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Carnation Wilt Diseases and Their Control

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Wilt diseases cause serious losses in greenhouse carnation culture in Massachusetts. This bulletin is intended to help the carnation grower understand these diseases and to acquaint him with proven control measures.

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CARNATION WILT DISEASES AND THEIR CONTROL

By E. F. Guba, Research Professor of Botany[1]

INTRODUCTION

The culture of carnations in greenhouses represents a large industry in Massachusetts and nearby adjoining areas. This industry is concentrated within a radius of 40 miles of Boston. Each year approximately 26,000,000 or more carnation cut flowers are produced in this area. The flowers are shipped to markets throughout the eastern half of the United States, as far south as Miami, Florida, and as far west as Chicago and St. Louis, and to nearby wholesale markets. In addition a large number of flowers is retailed on the growers' premises, for which no accurate production figures are available. The average gross return to the grower over several years prior to the war period has been about 3¼ cents per flower. The climate and soil in New England seem especially well adapted to carnation culture and to the production of flowers with desirable keeping and shipping qualities.

The industry has experienced large losses from carnation diseases, notably from blight caused by the fungus *Alternaria dianthi* and branch rot caused by *Fusarium dianthi*, and other diseases collectively manifesting the common symptom of wilt. The occurrence of the blight disease in epidemic proportions annually over several years, and the importance of the carnation cut flower industry in Massachusetts, have offered adequate justification for this study and for a broad treatment of the general subject of carnation diseases.

The subject matter of this paper has been arranged essentially into sections conforming to the various stages or practices in carnation culture. Information is presented regarding desirable treatments and cultural methods in relation to the control of carnation wilt diseases. The contributions of earlier investigators are freely offered. This procedure has seemed desirable in view of an extensive literature, especially from the United States and England, with which our growers are not familiar.

CLASSIFICATION OF CARNATION WILT DISEASES IN MASSACHUSETTS

The fungous diseases of greatest consequence encountered in the culture of carnations in Massachusetts are spot, blight, and canker caused by *Alternaria dianthi* Stev. & Hall.; root and crown rot caused by *Fusarium avenaceum* (Fr.) Sacc., *Fusarium culmorum* (W. G. Smith) Sacc., and other Fusarium species; branch rot or Fusarium wilt caused by *Fusarium dianthi* Prill. & Delacr.; and stem rot caused by *Rhizoctonia solani* Kühn. Symptoms of diseased carnation plants associated with these pathogenic organisms are wilting, yellowing, browning, and death of the branches or the entire plant. Distinctive and characteristic manifestations of disease are peculiar to each causal organism. The principal and most distinctive symptoms are expressed by various appropriate common names. Some common names have been employed rather loosely or without the scientific Latin counterpart, and this has led to some confusion in the literature.

[1]The author appreciates gratefully the generous cooperation and goodwill of the carnation growers of Massachusetts and the New England Carnation Growers' Association in his service to their industry.

Spot, Blight, and Canker

This disease, caused by the fungus *Alternaria dianthi* Stev. & Hall (Fig. 1, 2), is manifested by spotting of the foliage, flowers, and stems; blighting of the foliage; and cankering and rotting of the branches, followed by wilting, browning, and death of the branches. The discolored diseased areas become covered with a black layer of spores especially under moist atmospheric conditions. The spots at first have a slightly purplish color and are surrounded by a halo; later they become brown and shriveled, and as they coalesce the disease assumes the character of blight. The calyx and corolla lobes are also infected, especially in the field. The branches are infected most frequently at the nodes just above the stem, and this is the most common form of infection among the benched plants in the greenhouse. The brown discolored areas at the nodes partially or completely girdle the branch. At first the fungus is restricted to the bark or outside of the cambium. Ultimately, the canker progresses deeper into the branch. The leaves become dull green and marked with whitish or pale streaks, and then wilt. The infected portion of the branch below acquires a brown or blackish color, and the dark-colored rot extends to the pith. Black crusts of spores form over the region of the branch where the rot is localized, and some of the black deposit remains long after the branch has died. The branches become completely desiccated and assume the color of straw.

The fungus is associated with a brownish or blackish basal and axillary decay of cuttings in the sand bench (Fig. 3).

History

The Alternaria blight of the carnation was recognized as one of the important plant diseases in the United States in 1905 and considerable damage was reported among varieties of the Mrs. Thomas Lawson type (Orton 48, Woods 81). In October 1902 Irving Gingrich of South Bend, Indiana, submitted blighted carnation plants to Professor B. O. Longyear, Michigan State College, with information that the disease was especially severe on the variety "White Cloud." The fungus was identified as *Macrosporium nobile* Vize. The writer learned of the specimen deposited in the Herbarium of the Department of Botany, Michigan State College, from a published record by Coons (20). Study of this material showed that the organism is *Alternaria dianthi* which was described seven years later (62) on the basis of material found in Raleigh, North Carolina. In the meantime, Clinton (14) reported a serious occurrence of the Alternaria disease on carnations in a greenhouse at Greenfield Hill, Connecticut; and Woods (82) reported that the disease was especially destructive to the varieties Enchantress and Lawson, designated the "softer types." The plants acquired the disease during their growing period in the field and were damaged seriously after benching.

More recently, the disease has been epidemic in the Northeastern States, notably New York, New Jersey, Pennsylvania (49), Virginia, Connecticut, Massachusetts, New Hampshire, and Maine. In this general area frequent serious instances of the disease and plant failures have occurred. Less frequent occurrences of the disease are recorded from Colorado, Indiana, Michigan, Missouri, Texas, and Wisconsin, and it was reported in 1932 to be a limiting factor in the production of light-colored varieties grown under lath near Los Angeles, California. The disease has been serious on carnations in certain portions of Canada, notably in St. Anne, Quebec; Lincoln, Middlesex, and Cobourg counties of Ontario; and also in garden patches of Dianthus throughout the province of New Brunswick, especially in the vicinity of Fredericton (16, 45). It has been reported on *Dianthus* sp. from Puerto Rico (54).

An Alternaria disease of carnations has been prevalent at San Remo and Porto Maurizio, Italy, and in Sicily (3, 13, 50, 66). The pathogenicity of the fungus was established. It was designated *Alternaria dianthi* with, however, no satisfactory degree of confirmation.

Sorauer (57) reported a spotting and blighting of carnations in Germany associated with attacks of an Alternaria fungus. Death of carnation flower buds in Czechoslovakia is reported to be due to *Alternaria brassicae* Sacc. var. *dianthi* Zimm. (84). Moesz (47) reported a disease of carnation in Hungary analogous to carnation blight and associated with a fungus regarded as *Alternaria dianthi* Stev. & Hall. McAlpine (43) described the fungus *Alternaria longispora* on withered portions of carnation leaves at Sydney, Australia.

In 1927, Corbett (21) in England reported a wilt disease, associated with a brownish basal stem decay, among carnation plants four months from the rooting stage. Inoculation of plants with a spore suspension of the Alternaria fungus produced all of the symptoms characteristic of the disease caused by the fungus *Alternaria dianthi*. Its introduction into England was unquestionably associated with the importation of infected cuttings from the United States at a time when the disease was prevalent and destructive here. Since the disease has not been reported further, it has apparently not become established (74).

TABLE 1. SPORE DIMENSIONS OF SPECIES OF ALTERNARIA AND MACROSPORIUM REPORTED ON MEMBERS OF THE CARYOPHYLLACEAE.

Host and Fungus	Spore Size (Microns)	Authority
Dianthus Caryophyllus		
Alternaria dianthi	26-123 × 10-20	Stevens & Hall, No. Carolina (62)
" "	31-70 × 10-15	Gingrich*, Indiana
" "	45-117 × 14-26	Guba, Massachusetts
" "	26-103 × 13-38	Corbett, England (21)
" "	45-72 × 12-19	Overholts, Pennsylvania (49)
" "	20-54 × 5-17	Natural host } Elliot (26)
" "	10-54 × 5-25	Synthetic Agar } Elliot (26)
" "	35-90 × 13-40	Bean Agar } Elliot (26)
" "	30-110 × 10-30	Passalacqua, Italy (50)
" "	30-90 × 10-20	" " "
" "	33-100 × 20-27	Moesz, Hungary (47)
A. brassicae var. *dianthi*	60-100 × 12-15	Zimmerman, Czechoslovakia (84)
" " " "	23-45 × 14-17	" "
A. longispora	100-160 × 16-25	McAlpine, Australia (43)
Macrosporium congestum	31-75 × 18-36	Bresadola, Italy (8)
M. dianthi	42-53 × 15-20	D'Almeida and da Camara, Portugal (2)
Dianthus plumarius		
M. dianthemphus	35-50 × 10-17	Hume, Florida (35)
Dianthus seguieri		
M. seguierii	30-70 × 10-16	Allescher, Germany (1)
Dianthus sp.		
M. nobile	60-80 × 40	Vize, England (17, 18)
Saponaria		
M. saponariae	50-80	Peck, New York (51)
" "	22-80 × 7-14	Young (83)
Silene		
M. truncatum	50 × 23	Fautrey and Lambotte, France (27)
M. verruculosum	45-95 × 22-38	Bubak, Switzerland (11)

*Original specimen of *Alternaria dianthi* from Terre Haute, Indiana, deposited in Herbarium, Dept. of Botany, Michigan State College, East Lansing, Michigan.

Species of Alternaria and Macrosporium on the Caryophyllaceae

Several species of Alternaria and Macrosporium have been described on members of the Caryophyllaceae, and they all appear to be distinct from *Alternaria dianthi* (Table 1). *Macrosporium nobile* Vize was found in dead stems and leaves of Dianthus at Forden, England, by Rev. J. E. Vize and originally reported by M. C. Cooke (17, 18). Later British accounts of *Macrosporium nobile* (19, 41, 42) described the fungus as being definitely parasitic to carnations in England. The type specimen, Vize, Micro Fungi Brit. No. 63, however, bears only the fungus *Heterosporium echinulatum* (Berk.) Cke., a prevalent fungus on Dianthus associated with small gray leaf spots. The Macrosporium described by Vize may be regarded as secondary and saprophytic. The name appeared once in the American literature (20).

Cash (12) reported *Alternaria dianthi* on blighted foliage of *Lychnis chalcedonica* L. collected at Sitka, Alaska. The writer's examination of this material revealed an abundance of Cladosporium, apparently parasitic, also some Heterosporium, and a trace of Alternaria which was inadequate for identification and might more properly have been ignored in the naming of the specimen. Seymour (55) listed *Cladosporium herbarum* (P). ex Lk. on many species of Dianthus and Lychnis, and apparently the same fungus is involved in the specimen in question. Bisby and others (7) reported *Alternaria dianthi* on *Dianthus barbatus* Linn. The specimen also bears the fungus *Heterosporium echinulatum* (Berk.) Cke. in much greater abundance. The fascicles of conidiophores arising from the stomata and dotting the blighted foliage belong to Heterosporium.

Inoculations of *Dianthus caryophyllus* and cabbage with conidia of *Alternaria dianthi* were readily successful on Dianthus and unsuccessful on cabbage (26). So far as is known, the fungus is restricted to the genus Dianthus. It has been reported on *D. tristus* Vel., *D. barbatus* Linn., *D. plumarius* Linn., *D. chinensis* var. *heddewigii* (Linn.) Regel, and *D. Allwoodii* Hort. (6).

Root and Crown Rot

This disease, caused by the fungi *Fusarium avenaceum* (Fr.) Sacc., *F. culmorum* (W. G. Smith) Sacc., *F. poae* (Pk.) Wr., etc., is featured by a progressive wilting, collapse, and browning of the entire plant. The roots gradually rot away to the root head. The base of the stem is invaded and rotted. Reddish areas appear among the brown decayed stem and roots. The generalized rotting of roots and crown which characterize this disease is caused by many species of Fusarium, of which the three mentioned are most commonly responsible. These organisms also cause a serious rotting of the snags and nodes in the branches, and wilting of the parts above the infection centers. The disease can be bad in two- and three-year-old flowering stock. These organisms also cause a common soft basal rot of cuttings during the rooting period in the sand bench and after transplanting. Frequently complete failures result among rooted stock.

Destructive occurrences of the disease are frequent in July and August among newly benched plants, especially in wet, poorly drained soil. The disease has been the subject of extensive studies by Dowson (24), White (71-75), and Wickens (77, 78).

Branch Rot or Fusarium Wilt

This disease, caused by the fungus *Fusarium dianthi* Prill. & Delacr., is characterized by browning of the conductive tissue, wilting, yellowing, and gradual rotting of the stem and branches, and straw-colored dead remains (Fig. 6).

The disease can be recognized by the slow wilting and withering of the individual branches accompanied by changes in color from normal to dull green, then to yellow or straw. There is a progressive discoloration of the vascular or conductive tissue from the normal pale green to a yellowish, reddish, and brownish color. Infection is established in the roots, in the stem, or in the branches. Wilting does not appear until the disease has advanced considerably around the periphery of the branch or stem above and below the point of infection. The branches are progressively invaded by the fungus through the conducting tissue from the stem, and the brown color and dry rot spread radially and vertically. Frequently only the branches on the rotted side of the stem wilt and change color. Ultimately, the entire plant succumbs. Plants may live harboring infection for a long time without showing symptoms of disease. Pinkish spore masses of the fungus are usually evident on the surface of the stem and in the base of the branches at the level of the soil. The fungus is essentially a vascular parasite causing a typical wilting of the branches and subsequently a dry rot of the stem and branches. The disease may appear at any stage in the culture of carnations, but the losses are most significant in the summer and fall months. In 1914 Peltier (53) proposed the name "branch rot" for this Fusarium wilt disease, and this name is generally used by the growers. It is also called Fusarium wilt (5, 78), which appears to be a more appropriate name. The causal fungus has more recently been designated *Fusarium oxysporum* Schl. f. *dianthi* (Prill. & Delacr.) Snyder and Hansen (56).

Stem Rot

This disease, caused by the fungus *Rhizoctonia solani* Kühn, is characterized by a progressive wilting, collapse, and browning of the entire plant, associated with a soft decay of the stem at the soil line. The foliage acquires a pale or dull greenish color. The leaves wilt slightly at first, then more generally, and finally the entire plant collapses. The stem at the soil level is soft and moist and the bark is easily rubbed off with the fingers. The wood beneath the decayed bark at first remains firm. The roots remain intact and attached to the stem. The stem of the dead plant becomes fibrous as disintegration continues. Compact brownish clumps or sclerotia of the fungus are present on the decayed bark, and the mycelium of the fungus is present about the stem and adjacent soil.

This fungus is an omnipresent inhabitant of soil. It attacks cuttings in the sand bench and propagating house; rooted plants in the flats (Fig. 7), where it causes a troublesome basal rot; and all subsequent stages of the plant in the field and in the greenhouse. The association of the Rhizoctonia fungus with the stem rot disease of carnations was established in 1899 (25), but even before that time the disease was widely distributed on carnations throughout the United States. Its occurrence in Massachusetts was reported in 1902 (64). The fungus attacks all kinds of plants and it has been the subject of extensive research (52, 53).

TEMPERATURE RELATIONS OF THE PATHOGENES CAUSING WILT

The optimum temperature for growth and for spore germination of the pathogenic organisms considered in this paper lies in a range of 75° to 88° F. The optimum and highest temperatures of the year prevail in the greenhouse in July and August, and after the benches are newly planted.

The optimum temperature for spore germination and growth of *Alternaria dianthi* is about 75° F., and at 40° and 90° growth is almost completely inhibited.

Fusarium avenaceum and *F. culmorum*, the root-rotting organisms, grow best at temperatures around 80° F. Dowson (24) reported that the optimum growth

temperature for these organisms was 79° and the maximum about 100°. White (71) stated that the optimum temperature for growth was generally above 77°, and Starkey (61) found that 80° was most favorable for infection. In Colorado (60, 61) the greatest losses from root rot occur in October at minimum temperatures somewhat above 50°. With temperatures maintained somewhat below 50° up to mid-December, the losses are reduced by more than one-half.

The optimum temperature for the growth of *Fusarium dianthi*, the branch rot organism, is about 80° F., the maximum about 95°. Van der Bijl (67) found that the optimum temperature was in a range of 77° – 86° and that no growth occurred at 32° and 104°. Wickens (78) found that 84.2° was the optimum temperature for growth in culture, strong growth occurred at 95°, and none at 50°. Bickerton (5) reported that the optimum, minimum, and maximum temperatures are approximately 80°, 43°, and 97° respectively.

The optimum temperature for growth of *Rhizoctonia solani*, the stem rot organism, is 86°–88° F. (53). High soil temperature and excessive soil moisture are both extremely favorable. When both these conditions are present, infection and the progress of the disease are greater than in the presence of either alone. The losses from stem rot are high in the months of July, August, and September but relatively insignificant during the colder months and in the warmer months of the spring season. With the advanced age and growth of the plants the stem rot disease is almost totally absent.

INFECTION

The subject of infection of carnations by the various important wilt producing pathogenes has been widely investigated and the important contributions on the subject are reviewed here.

Alternaria Spot, Blight, and Canker

Severe infection not predisposed by injuries can occur at the leaf axils where the fungus is favored by the retention of moisture (62). Corbett (21) observed circular discolored areas with black centers on leaves and stems following inoculation of carnation plants with a water suspension of spores of Alternaria, and the inoculation of a freshly cut stem caused a dying back to the node and the wilting of the adjacent branches.

Injured plants are readily infected (62). Foliage injuries from drought, chemicals applied to control pests, and infestations of red spider mite can contribute to serious incidences of Alternaria blight in the field. The pointed tips of the leaves sometimes die from drought conditions and then are invaded by the fungus which subsequently progresses farther into the leaf blade. The leaves of two potted carnation plants were injured by pricking them with a needle; two other plants were not so injured. The plants were sprayed with spores in water and incubated in a damp atmosphere. The needle-pricked plants showed 117 distinct infections in contrast to 63 on the uninjured plants.

The Alternaria blight disease can be readily produced artificially by spraying carnation plants with a water suspension of spores of the fungus and incubating the plants in a humid atmosphere. These single spore infections appear as numerous small purple spots each surrounded by a halo (Fig. 4). Subsequently areas in the leaves and flowers wither and turn brown and become covered with a black mass of spores. Infection is readily obtained in this way on varieties which show resistance under natural conditions in the field. Infection is also readily obtained by inserting a piece of the fungus from culture in the axils of the flowering branches and maintaining a moist swab of cotton about the point of inoculation.

Fusarium Root and Crown Rot

The generalized rotting of carnation roots, stems, and branches due to several distinct species of Fusarium is well known. Starkey (58, 59, 60, 61) traced the development of the disease from the fine roots in the remote parts of the root system to the crown and into the stem. The roots decay and slough off and infection spreads from root to root in the soil. Plants with sound roots were not infected in soil inoculated with spores of *F. culmorum* or in contaminated soil under conditions favorable for good root action (71, 72, 74, 76, 78), but cuttings planted in contaminated sand readily succumbed. Spores or pieces of culture of *F. culmorum* applied to stabs in the stems and to wounds at the nodes or to the cut ends of stems caused rotting at the point of inoculation and dying-back of the branches. Dowson (24) reported that infection occurs only through wounds in the presence of high temperature and high soil and atmospheric moisture.

Both *Fusarium culmorum* and *F. avenaceum* are associated with a devastating basal rot of cuttings in sand and of the roots of plants in subsequent stages of growth. These organisms are active pathogenes, but well-established uninjured plants growing under favorable cultural conditions are never affected. In a few instances devastating cases of root rot have been noted in association with both a heavy soil infestation of garden symphylids and poor growing conditions—essentially wet soil and the absence of good drainage—and the latter factor appeared more significant than the small amount of root injury caused by the symphylids. Nevertheless, these creatures are general feeders and destroy the fine roots, and consequently can be regarded as a contributing factor. White (74, 76) stated that injuries to the roots by wireworms and wood lice contributed to root rot infection after planting. Severe damage from *F. culmorum* has been noted after the flowering stock had been mulched with manure; in other instances following applications of concentrated chemical fertilizers, and also following the use of cuttings from stock plants showing a prevalent rotting about the nodes and snags in the branches.

The importance of injuries in relation to infection was confirmed by a series of demonstrations. Bits of inoculum from authentic cultures of *F. avenaceum* and *F. culmorum* were transferred to axils of flowering shoots of Nina Brener carnations in June, twelve months after benching. The points of inoculation were wrapped in moist cotton. Rotting followed only where the cutting in the axil had been removed. Transfers of similar inoculum into incisions in the stem were successful; without incisions infection failed. With an authentic culture of *F. culmorum* from England, eleven inoculations through injuries in the stems of young potted plants yielded positive infections; without injuries five stem inoculations were negative and three were positive. With an authentic culture of *F. poae* from Germany, eight of the nine inoculations at injuries in the stems developed active cankers and nine inoculations made without injuries failed to cause infection. With a culture from England designated *F. herbarum* (Corda) Fr. = *F. avenaceum* (Fr.) Sacc., nine inoculations yielded six positive infections when the inoculum was applied to injuries and only negative results when the inoculum was applied to the stem without injuries. With an authentic culture of *F. avenaceum* from Germany, decay and dying back of the branches followed nine inoculations at injuries; inoculum applied to stems not injured at the point of inoculation also yielded positive infections. With *F. sporotrichioides* Sherb. from Germany, six inoculations at injuries were positive and three were negative; without injury all were negative. In these tests infection following inoculations with *F. poae*, *F. avenaceum*, and *F. culmorum* were particularly devastating. When the inoculum from pure cultures of these organisms was buried in the

soil about injured roots and the plants cared for in the ordinary way, no disease symptoms developed.

Fusarium Branch Rot

Peltier (53) reported that the branch rot fungus infects carnation plants through wounds. Wickens (78) showed that cuttings planted in contaminated sand or inoculated at wounds were a total loss. Infection was established at the cut surface at the base of the cutting. Inoculations were usually successful through wounds but never through unwounded tissue. Wight (79) reported that soil contamination with the fungus was not likely to cause disease in sound plants. Van der Bijl (67) obtained successful infections by inserting pieces of cultures of the fungus into needle pricks in the stems below the natural soil level. Bickerton (5) reported successful infections of young rooted plants by inserting inoculum of the pathogen into wounds at the base of the stem and by dipping the roots into a water suspension of spores. It appeared to him that the large majority of infections are initiated in the roots. Similar evidence was secured by the writer.

Pure culture material of *Fusarium dianthi* containing an abundance of spores was macerated and added to sterile water. Forty rooted cuttings of each of eighteen varieties were washed free of sand and then immersed in the water suspension of spores and planted in steam-sterilized soil in flats. Within a month most of the plants of some varieties were totally destroyed; others showed symptoms of infection. The fungus was easily isolated from both the roots and stems, and the path of the fungus high up in the shoots was recognized by the discoloration of the water-conducting tissue. Obviously the roots were injured in lifting the plants from the sand, thus assisting the fungus in its infection process.

In the general area of New England the branch rot disease appears throughout the year among established plants and is usually most prominent after the benching season, 5 to 8 months from propagation. At this time the temperatures are excessive, frequent watering is required, and the plants have experienced considerable injury from handling and transplanting. As the plants resume growth and the weather becomes colder, the disease progresses more slowly and is masked by the fresh green growth, but it becomes important again in the warm months after winter. The disease is especially troublesome in certain varieties and among some classes of stock, indicating that the continuity of the disease is closely bound up with cuttings from contaminated stock plants.

In the writer's experiments, 12 transfers from a culture of the fungus into incisions in the stems and branches on well-established plants 10 months from the cutting stage were all positively successful as against 6 similar inoculations made without incisions, of which 5 were negative and 1 positive. In another instance in June, 11 months after benching, plants of Nina Brener were inoculated by placing bits of a culture of *Fusarium dianthi* in the axils of the leaves and then swabbing the points of inoculation with moist cotton. Infections were positive only when the inoculum was placed in an axil from which a cutting or axillary branch had been torn out.

It appears definitely that injuries are necessary for infection. Natural checking of the base of the stems of the cuttings during and after rooting is a common phenomenon. These openings provide favorable infection courts for the fungus (24, 79). Injuries to the plants in transplanting into the field and back into the greenhouse contribute greatly to the disease, but this seems almost unavoidable if the plants are grown outside.

The incubation period is ordinarily long but under warm atmospheric conditions the disease progresses rapidly. Bickerton (5) reported 92 percent infected plants at a soil temperature range of 70°–80° F. in 23 to 45 days, and 39 percent at 50°–65° in 56 to 75 days, following inoculation of the roots. Under the cool conditions of the winter months, infection remains latent for some time. As the disease appears among scattered plants abundant inoculum is provided for secondary infections in subsequent stages of culture. Thus under favorable conditions the amount of disease may run high among certain classes of stock.

Rhizoctonia Stem Rot

The Rhizoctonia stem rot fungus grows in the soil and attacks one plant after another. Infection is readily induced by placing a culture of the fungus in contact with the stem at the soil line and maintaining moist conditions. Infection is more generally successful by direct insertion of bits of the fungus into incisions in the plant (25). Pieces of Rhizoctonia from culture were inserted in scalpel slits in the stems of Nina Brener carnations in June, 9 months after benching, and in other instances the fungus was placed on the stem at the level of the soil and swabbed with moist cotton. One of 9 inoculations on uninjured stems was positive; 5 of 6 inoculations in scalpel slits in the stem were positive.

Conditions which both favor the fungus and place the plant at a disadvantage contribute to occurrences of the disease. Infection is readily induced by mixing the fungus with the soil in which the plants are growing. Peltier (52, 53) reported that the disease is most progressive at temperatures of 86°–88° F. and soil moisture either too high or too low for the best growth of the plants, and he considered wounding necessary for infection. The fungus enters through cracks in the corky layer of the bark near the surface of the soil. More stem rot is observed among deeply set plants branching below the soil surface than among those with a single stem in the soil. Infection among old plants was high following inoculation of the stem at wounds below the natural soil level (52). Destruction of cuttings and young plants readily follows when the sand or soil is inoculated with the fungus and when favorable temperature and moisture conditions are provided. The fungus is widespread in all types of soil and more virulent in some than in others. The occurrence of carnation stem rot is largely influenced by conditions created by the grower, which are favorable to the fungus and unnecessary for the best growth of the plants; and this was recognized early in the history of American carnation culture. Serious occurrences of the disease even then were considered the result of deep planting, excessive soil moisture, and imperfect drainage (40, 68).

STOCK PLANTS AND THE SELECTION OF CUTTINGS

The importance of selecting cuttings from healthy stock plants is generally stressed in the literature. The risk of serious losses from ignoring this rule is usually very great, particularly in relation to Alternaria blight, Fusarium root rot, Fusarium branch rot, and carnation rust caused by the fungus *Uromyces caryophyllinus* (Schr.) Wint. These pathogenic organisms exist in the foliage and branches. Starkey (58, 59, 60) reported that at the end of 63 days 83.3 percent of the plants had died from Fusarium root rot as the result of propagating cuttings gathered from diseased branches, and that only 38.1 percent of the cuttings rooted. After 160 days only 7 plants survived. In contrast, 94 to 98 percent of the cuttings from healthy stock plants remained healthy. Wickens (78) noted that healthy cuttings contaminated with the Fusarium root rot organism rapidly succumbed to basal rot.

White (75) found that 42 percent of the cuttings from a bed containing diseased plants were contaminated with fungi of which 7 percent were *Verticillium cinerescens* Wr., the cause of a serious wilt disease of carnations in England. In another instance 22 percent of the cuttings yielded organisms associated with carnation wilt diseases, 38 percent yielded organisms not suspected of causing wilt, and 40 percent of the cuttings were clean. The carry-over of the Verticillium wilt fungus occurs mainly when the cuttings are taken adjacent to visibly diseased areas, but in practice some cuttings are infected even when precautions are taken to avoid the neighborhood of diseased areas (77, 78). The fungus was isolated from parts of shoots well beyond the limits of any microscopically visible internal or external symptoms. Wickens (78) isolated *Fusarium dianthi* freely from branches which externally appeared perfectly sound, but only within the limits of some alteration in the conducting tissue. Bickerton (5) obtained the branch rot fungus from off-colored, and frequently from green cuttings from apparently healthy plants growing adjacent to diseased plants. Sometimes the fungus was found in the shoots of infected plants even in the absence of any visible discolorations of the vascular tissue. Sturgis (65) felt that the outbreak of the disease in his experiments was due to the presence of the fungus in the tissues of the original cuttings.

In the Boston area serious losses from the Fusarium root rot organism have been observed in the propagating house and among young rooted plants in flats or beds in the early months of the year. The axils of the flowering branches from which cuttings are taken provide collecting places and reservoirs for water. Water is a carrier of fungous spores and thus it is not uncommon to note discolored infected tissue at the nodes. The Alternaria blight fungus and the Fusarium root rot fungus are frequently found associated with discolored or decayed tissue at the nodes of the branches. A basal decay of the cuttings follows when cuttings from such sources are planted in sand. The snag in the branch or the point

TABLE 2. RESULTS OF TISSUE TRANSFERS FROM CARNATION CUTTINGS TO ARTIFICIAL CULTURE MEDIA.

Variety	Source	Number of Platings	Number of Isolates		Transfers Dipped in Alcohol and Flamed Before Plating		
			Alternaria	Fusarium	Number of Platings	Number of Isolates	
						Alternaria	Fusarium
Fairy Queen	De Vita	117	11	4	57	0	0
Boston Ward	De Vita	95	0	0	27	0	0
Wardelia	Jahn	84	1	6	64	0	0
My Love	La Montagne	69	1	0	24	0	0
Boston Ward	La Montagne	58	1	1	34	1	0
Boston Ward	Rice	63	1	0	25	0	0
Matchless	Rice	25	3	0	16	0	0
Nina Brener	Farr	97	0	0	40	0	0
Matchless	Brigham	26	0	4	42	0	9
Boston Ward	Brigham				11	0	0
Nina Brener	Brigham				15	0	0
Matchless	Littlefield-Wyman				47	0	0
My Love	Littlefield-Wyman				17	0	0
Scarlet Monarch	Littlefield-Wyman				22	0	0
Nina Brener	Shaw				74	0	1
Total		634	18	15	515	1	10
Percent			2.84	2.37		0.19	1.94

where the cutting has been removed may become infected with the Fusarium root rot fungus and cause the wilting of the branch. Since the dieback of the shoots and wilting sometimes occur in consequence of spore-infected snags or at injured axils in the branches, it is apparent that the cuttings become inoculated on the stock plants with any one of several pathogenic organisms though they may appear healthy and desirable for propagation.

Growers were requested to collect batches of cuttings as if for their own propagation and to submit them to the writer for study. Laboratory examination revealed discolored tissue about the nodes in some instances. Transfers of tissue from the nodes and base of the cuttings were made to sterile culture media in petri dishes. Both Fusarium and Alternaria were occasionally obtained (Table 2).

The greenhouse atmosphere and growing beds of a carnation range are obviously never completely free of pathogenic fungi, however healthy the flowering stock may appear. The avoidance of diseased areas in a range showing more or less disease is not so completely effective in preventing the transfer of contamination as selection in an environment of generally healthy stock. The population of the fungus in the environment of the plants bears some relation to the extent of the disease. Thus a greenhouse kept sanitary by the successful control of disease is obviously important in relation to propagation. The transmission of pathogenic organisms either as hidden infection or as spores lodged on the cuttings can be serious, and unless it is adequately combated, desirable effective control measures in later stages of culture can be defeated.

PREPARATION AND DISINFECTION OF CUTTINGS

Trimming

Carnation cuttings are frequently inserted in the sand without trimming or further preparation. A smooth, horizontal cut with a sharp knife at the base of the cutting to remove the loose remnants of tissue has been advocated (71, 72, 76) on the presumption that a jagged, sloping surface encourages an uneven formation of roots and increases the risk of decay. Our growers also obtain satisfactory results from a clean diagonal cut, which gives a larger area for the growth of roots. Lamborn (39) wrote that the slips can be broken off with the fingers and put directly in the cutting bed without the use of a knife and they will root as certainly as if trimmed and smoothly cut at the end. Rooting the cuttings without trimming them is time and labor saving, but trimming makes it possible to plant more cuttings in a given area of sand. The extra operation of trimming the cuttings is desirable since it offers the opportunity of scrutinizing them and discarding any showing imperfections. There appears to be no evidence against either method so far as disease is concerned.

Soaking in Water

The practice of soaking carnation cuttings in water before they are planted can be the means of spreading disease, especially if the cuttings are infected or come from infected stock plants or contaminated areas in the benches. In water, the cuttings generally may become inoculated by spores freed from a single diseased cutting, and outbreaks of carnation rust in the young stock result from this practice. Creager (22) reported that the soaking of carnation cuttings in water contributed to the spread of bacterial wilt caused by *Phytomonas caryophylli* Burk. among the young stock. Kirby (36) reported that soaking cuttings for one hour caused 18 percent of them to become infected with Alternaria in contrast to 92 percent of those soaked 4 hours.

In view of the continual redistribution of spores among the stock plants in the benches by water, air currents, or even cultural practices, some infection is possible among apparently clean cuttings. It would seem best either to wash the cuttings under a spray of cold water or to soak them briefly in water and then allow the water to drain off. Subsequently they might be kept moist in a cool atmosphere until they can be trimmed and planted. Cuttings soaked in water for several hours do not root well and can be a total failure.

Disinfecting Chemicals

Action on Fungous Spores

The presence of spores of pathogenic organisms on the cuttings suggests the desirability of disinfecting them before they are placed in the sand. A chemical disinfectant for this purpose must meet certain rigid requirements. It must not inhibit rooting or injure the cuttings in any way. The treatment would be advantageous if it could hasten and improve rooting in addition to providing some degree of disinfection. The toxicity of many chemicals to the conidia of the Alternaria blight fungus and of other organisms pathogenic to carnations was studied (Fig. 5).

Small pieces of diseased carnation plant tissue bearing spores of *Alternaria dianthi*, *Fusarium dianthi*, and *Uromyces caryophyllinus* and of tomato leaf tissue bearing spores of *Cladosporium fulvum* Cke. were immersed in solutions of certain chemicals selected for their mild fungicidal properties, in the effort to find a safe treatment offering some degree of disinfection. The small pieces of sporulating tissue were immersed and soaked for a period of 5 to 15 minutes, then washed with fresh water and drained, and then incubated at laboratory temperature.

Solutions of potassium permanganate varying in concentration from saturation to 1-2,000 were tested. This chemical is a mild fungicide, and has some use for that purpose in horticultural practice. A saturated solution was generally and consistently toxic, but as the concentration was weakened in gradual steps to 1-2,000 toxicity was not consistent. The results with the same solution were frequently reversed and this was true of both 1-500 and 1-2,000 solutions; but trials in which germination was completely suppressed were frequent enough at a 1-1,000 dilution to make it desirable for disinfecting carnation cuttings. It was apparent that factors not well understood were present which accounted for complete toxicity in many trials and incomplete toxicity or the absence of it in others.

Spores of Alternaria immersed in drops of potassium permanganate 1-500 to 1-2,000 and incubated for 48 hours, then immersed in fresh water and incubated further, failed to germinate. Likewise when the spores were immersed in fresh solutions for 30 to 100 minutes there was no germination. When the spores were immersed in drops of 1-500 and 1-1,000 solutions on glass slides, dried in the laboratory for 30 minutes, and then incubated in moist Petri dishes, the viability of the spores was lost. By this method a 1-2,000 solution was not toxic.

Small pieces of infected leaf areas bearing Alternaria spores were soaked in solutions of potassium permanganate 1-500, 1-1,000, 1-1,500, and 1-2,000 for 5, 10, and 15 minutes and then washed clean with dribbles of fresh water from a medicine dropper. The mounts were then immersed in a drop of fresh water and incubated for spore germination. The solutions were tested for their toxic effect at regular intervals after preparation. Concentrations of 1-1,500 and 1-2,000 were hardly toxic in the 5 or 10 minute immersion periods, even when the solutions were freshly made. The tests showed almost complete loss of fungicidal

value after 7 to 10 days from the date of preparation. The spores of the carnation rust fungus seemed to be much more tolerant of potassium permanganate, but immersion of sori longer than 30 minutes and for as long as 48 hours destroyed the power of the spores to germinate.

When King Cardinal cuttings were dipped in a water suspension of spores of the Uromyces rust fungus and then immersed in water for 15 hours, 32.8 percent showed rust pustules after growing in the sand for 24 days. In contrast, only 3.2 percent of the cuttings immersed in potassium permanganate 1-1,000 for 45 minutes and kept moist over night showed rust. Immersed in potassium permanganate for 15 hours, 1.2 percent of the cuttings showed rust; immersed in water for 45 minutes and kept moist over night, 72.8 percent of them were infected. In other tests the amount of disease was determined from a count of the infections in the blades and stems. Infection at the base of the stem was indicated by decay or discoloration or both. This was regarded as a separate infection and was added to the number of infections found elsewhere on the cuttings to obtain the total. The value of potassium permanganate as a disinfectant is shown in Tables 3, 4, and 7. Beginning with the earliest tests conducted in 1931, the results with potassium permanganate have been outstanding.

Malachite green was consistently toxic in dilutions up to 1-40,000 and strong effect was shown in a range of 1-20,000 to 1-40,000. At weaker dilutions considerable germination was noted. The consistent fungicidal effect of malachite green at these weak dilutions represented a distinct contrast to that obtained from potassium permanganate. The toxic effect of malachite green 1-25,000 to the spores of the rust fungus was more rapid and complete than that of potassium permanganate 1-1,000. Howard (34) found that malachite green at great dilutions is strongly fungicidal to the spores of *Alternaria solani* (Ell. and Mart.) Jones and Grout. A similar effect upon *Alternaria dianthi* is shown here. Nevertheless, the control of disease among artificially inoculated cuttings immersed in malachite green solution has not been satisfactory (Tables 7, 8, 9). More study is needed.

TABLE 3. EFFECT OF CHEMICAL SOLUTIONS ON ROOTING OF BOSTON WARD CARNATION CUTTINGS AND CONTROL OF ALTERNARIA.

Treatment (5 Minutes)	Number of Cuttings	Percent Rooted	Number Infections Per 100 Cuttings
A			
Mercuric Bichloride 1-1,000	512	0.0	2.3
Uspulun 2.3 gms.-1,000	595	6.5	7.5
Potassium Permanganate 1-1,000	1159	79.8	16.0
Bordeaux 4-4-50	1278	41.4	21.6
No Treatment	676	71.9	50.2
B			
Potassium Permanganate 1-1,000	85	80.0	10.5
Uspulun 2.3 gms.-1,000	142	9.1	6.3
Bordeaux 4-4-50	102	7.8	7.8
No Treatment	96	57.3	28.1
C			
Potassium Permanganate 1-1,000	353	90.0	12.4
Bordeaux 4-4-50	393	52.9	12.2
No Treatment	317	73.8	51.7

TABLE 4. EFFECT OF CHEMICAL SOLUTIONS ON ROOTING OF MATCHLESS CARNATION CUTTINGS AND CONTROL OF ALTERNARIA. CUTTINGS PREVIOUSLY IMMERSED IN A WATER SUSPENSION OF SPORES OF ALTERNARIA.

Treatment	Number of Cuttings	Percent Rooted	Number Infections Per 100 Cuttings
(5 MINUTES)			
Potassium Permanganate 1-1,000	100	94	56
Same, plus 0.12 percent Fish Oil	100	93	4
Water	50	24	1108
Water*	50	84	0
(10 MINUTES)			
Potassium Permanganate 1-1,000	100	84	16
Same, plus 0.12 percent Fish Oil	50	78	36
Same, plus Kayso 0.5 gms.	50	94	16
Same, plus Saponin 0.5 gms.	50	100	62
Water	100	87	139
Water*	50	100	0
(15 MINUTES)			
Potassium Permanganate 1-1,000 (new)	147	71	38
Potassium Permanganate 1-1,000 (old)	142	79	56
Water	76	43	197
Water*	74	69	16

*Not inoculated.
Fish Oil, Saponin, Kayso added to improve wetting.

Methylene blue solutions of 1-1,000 to 1-4,000 were studied. Solutions of 1-1,000, 1-2,000 and 1-3,000 were most frequently toxic. The results were often reversed, and in this respect methylene blue appeared like potassium permanganate. The immersion of carnation cuttings in a 1-3,000 methylene blue solution did not give satisfactory control of disease.

Solutions of Orange and Yellow Helione* in concentrations of 1-200 to 1-800 were inconsistently toxic. They were toxic at the strongest concentration more frequently than not, but appeared generally not promising.

Effect on Rooting and Disease Control

Guba (28) reported a notable improvement in the rooting of carnation cuttings by immersing them for 5 to 15 minutes in a 1-1,000 solution of potassium permanganate prior to planting. Disinfection of the cuttings was also claimed for the treatment. In subsequent articles on carnation diseases, this treatment of the cuttings has been endorsed repeatedly (29, 30, 31, 32, 33). The recommendation is based on favorable results obtained in laboratory experiments and in commercial propagating houses (Tables 3, 4, 7, 12).

Carnation cuttings immersed in potassium permanganate solution acquire a darker green color and show a greater growth of roots and foliage during their growing period in the sand than untreated cuttings. Such a response in the propagation of carnation cuttings is very desirable.

*Standard Agricultural Chemicals, Inc., Hoboken, N. J.

TABLE 5. EFFECT OF CHEMICAL SOLUTIONS ON ROOTING OF VIRGINIA ROSE CARNATION CUTTINGS.

Treatment (15 Minutes)			Percent Well Rooted	Percent Not Rooted
Mercuric bichloride	1-1,000	5 minutes*	87.8	4.0
Methylene Blue	1-3,000		89.6	5.1
Malachite Green	1-25,000		61.2	15.3
Orange Helione	1-200		78.3	8.2
No Treatment			89.1	8.4

*Thoroughly washed after chemical treatment and then trimmed.

TABLE 6. EFFECT OF SOLUTIONS OF MALACHITE GREEN ON ROOTING OF CARNATION CUTTINGS.

Treatment (15 Minutes)	Percent Rooted		Percent Rooted				
	Rinsed in Water		Not Rinsed in Water				
	Peter Fisher	Puritan	Nina Brener	Olivette	Peter Fisher	Puritan	Boston Ward
Malachite Green							
1-20,000	35.2	78.5	100	100	58.8	100	97
1-30,000	64.7	100	86.6	97	47	71.4	97
1-40,000	43.7	85.7	82.7	100	47	78.5	92
1-50,000	35.3	100			44.4	85.7	
No Treatment	35.3	100	90.3	100	11.7	92.8	100

TABLE 7. EFFECT OF CHEMICAL SOLUTIONS ON ROOTINGS OF PURITAN CARNATION CUTTINGS.

Cuttings previously immersed in a water suspension of spores of *Alternaria Dianthi* and *Fusarium Dianthi*.

Treatment (1 Hour)	Percent Well Rooted	Percent Not Rooted
Potassium Permanganate 1-1,000	47.9	47.9
Methylene Blue 1-3,000	18.0	65.0
Malachite Green 1-25,000	1.0	91.0
Water	11.4	80.4

Malachite green, in 1-1,000 and slightly weaker solutions, was harmful to rooting. Frequently, the type of rooting following immersion in malachite green solutions 1-20,000 and weaker was not satisfactory; at other times no injurious effect was shown (Tables 5, 6, 7, 8, 9). The root-inducing effect and the greater vigor of the cuttings associated with the use of potassium permanganate solution was not shown with malachite green.

When cuttings were immersed in a 1-1,000 solution of methylene blue, the rooting was not satisfactory. Sometimes there was no harmful effect from a 1-3,000 solution (Tables 5, 7). The results of immersing untrimmed carnation cuttings for 5 minutes in a 1-1,000 solution of mercuric bichloride, followed by washing, trimming, and rinsing in fresh water, were inconsistent (Tables 5, 9).

Cuttings so treated usually rooted less than those immersed in water or not treated at all. Injury seemed to occur even though, after the treatment and rinsing in water, the basal portion of the stem was cut away to the next node before the cutting was planted in sand. For this purpose the use of this material in practice would be hazardous.

TABLE 8. EFFECT OF CHEMICAL SOLUTIONS ON ROOTING OF NINA BRENER CARNATION CUTTINGS AND CONTROL OF DISEASE. Cuttings previously immersed in water suspension of spores of *Alternaria dianthi* and *Fusarium dianthi*.

Treatment (15 Minutes)	Percent Rooted	Percent Infected	
		Rooted	Total
Malachite Green			
1-20,000	86.5	13.3	23.3
1-30,000	93.0	15.2	18.7
1-40,000	93.2	18.0	22.9
No Treatment (Water)	92.9	20.6	25.7

TABLE 9. EFFECT OF CHEMICAL SOLUTIONS ON ROOTING OF NINA BRENER CARNATION CUTTINGS AND CONTROL OF DISEASE. Cuttings previously immersed in a water suspension of spores of *Alternaria dianthi* and *Fusarium dianthi*.

Treatment (15 Minutes)	Percent Rooted		Percent Infected	
	Good	Poor	Rooted	Not Rooted
Malachite Green 1-25,000	56.0	8.0	43.7	73.3
Same, washed	46.1	23.0	33.3	74.9
Malachite Green 1-25,000 Vatsol 2-25,000	53.8	11.5	5.8	55.5
Same, washed	64.0	8.0	5.5	57.1
Malachite Green 1-40,000	44.0	8.0	23.0	50.0
Same, washed	46.1	15.3	12.5	60.0
Malachite Green 1-40,000 Vatsol 2-25,000	33.3	4.1	11.1	53.3
Same, washed	64.0	4.0	0.0	85.0
Mercuric Bichloride 1-1,000*	46.1	15.3	18.7	50.0
Same, plus Vatsol 2-25,000*	46.7	8.3	7.7	27.2
Water	88.0	0.0	68.1	33.3
Water**	88.0	8.0	2.2	100.0

* Trimmed and washed after treatment.
** Not inoculated.
Vatsol added to improve wetting. Supplied by American Cyanamid and Chemical Corp., Pittsburgh, Pa.

Preliminary tests with organic fungicides indicate the value of Arasan and Fermate* on the control of disease (Tables 10 and 11).

*Tetramethylthiuram disulfide and ferric dimethyldithiocarbamate respectively.

TABLE 10. EFFECT OF CHEMICAL POWDERS ON ROOTING OF OLIVETTE CARNATION CUTTINGS.
Basal section of cuttings dipped in powder, then planted in sand.

Treatment	Percent Well Rooted	Percent Poorly Rooted
Fermate	97.1	0.0
Talc	54.2	11.4
(Dithane)HE-175 10%-Talc 90%	40.0	5.7
Arasan 10%-Talc 90%	88.5	5.7
Spergon 10%-Talc 90%	48.5	14.2
Fermate 10%-Talc 90%	74.2	0.0
No Treatment	62.7	11.4

TABLE 11. EFFECT OF CHEMICAL POWDERS ON ROOTING OF OLIVETTE CARNATION CUTTINGS AND CONTROL OF DISEASE.
Basal portion of cuttings immersed in spore suspension of *Fusarium dianthi*, then dipped in fungicidal chemical powder before being planted in sand.

Treatment	Percent Rooted		Percent Infected
	Well	Poorly	
Fermate	57.1	8.5	8.5
(Dithane) HE-175 10%-Talc 90%	0.0	0.0	85.1
Arasan 10%-Talc 90%	48.5	17.1	14.2
Spergon 10%-Talc 90%	52.7	19.3	11.1
Fermate 10%-Talc 90%	62.3	8.5	2.8
No Treatment	0.0	11.4	85.7

No injurious effect on rooting was shown by Arasan or Fermate, and the control of Fusarium wilt was striking.

The value of adding these materials to hormone powder as a means of combining both root-inducing action and disease control in the same treatment of the cuttings before planting in sand is indicated. Study is required to determine the effect of immersing carnation cuttings in a water bath of these chemicals on the control of other carnation diseases and on rooting.

Hormone Materials

Kirby (36, 37) reported that dusts containing indolebutyric acid or naphthyl acetamide were more effective in disease prevention than a dust containing naphthalene acetic acid, and that all of them and thiourea controlled Alternaria better than potassium permanganate alone. It was implied that these chemicals in talc are more fungicidal than thiourea in talc. The results were based on the condition of Puritan cuttings as they were taken from the sand.

The effect of these hormone materials on spore germination of the same Alternaria organism was studied by the writer. The spores from infected plant material were applied to glass slides with a camel's-hair brush. Subsequently, the slides were dusted with different brands of hormone powders or sprayed with different brands of hormone solutions, corresponding to the concentration

recommended by the manufacturer for rooting carnation cuttings. Spores in drops of these hormone solutions were also placed on glass slides and incubated in moist Petri dishes. The following hormonized powders were used:

Rootone (Old Type)	American Chemical Paint Company
Rootone (New Type)	American Chemical Paint Company
Hormodin No. 1 Powder	Merck and Company
Root-Gro	Root-Gro Chemical Company
Thiourea 1-2,500 in Talc	

The following quantities of hormonized solutions were used in ½ pint of water:

Hormodin A	0.6 cc	Merck and Company
Root-Gro Concentrate	12.5 cc	Root-Gro Chemical Company
Auxilin	0.6 cc	Pennsylvania Chemical Corporation

No toxicity to the spores was revealed. Spore germination appeared to be accelerated by all, irrespective of the active ingredient peculiar to each brand. The powders or solutions could not be considered fungicidal and no claims to that effect are made by the manufacturers.

The idea of treating carnation cuttings with hormone powders and solutions was introduced at a time when carnation growers had already adopted the practice of soaking the cuttings in potassium permanganate solution before planting them in sand. Thus the two practices appeared to conflict. It is reported that potassium permanganate inactivates the hormone substance and that when both are used the root-inducing substance should be applied last (22, 23).

Kirby (36, 37) reported the least percentage of diseased cuttings due to Alternaria, the greatest fresh weight, and the best rooting from immersing the cuttings in potassium permanganate solution, then washing them, and subsequently dipping the cut ends in a hormone dust. He found that when the cut ends of carnation cuttings were dipped in naphthalene acetic acid dust, 17 percent of the cuttings showed Alternaria branch rot in contrast to 26 percent of those immersed for 10 minutes in a 1-1,000 solution of potassium permanganate and 60.5 percent of those not treated. When the cuttings were immersed 10 minutes in potassium permanganate solution, washed, and the cut ends then dipped in naphthalene acetic acid dust, the percentage of diseased cuttings was reduced to 5 percent. Since the brands of hormone materials studied are not fungicidal to spores of the organisms pathogenic to carnations, the control reported by Kirby (36, 37) is obviously not due to the action of the dust upon the spores of the Alternaria pathogene. Experimental trials repeating the procedure and materials employed by Kirby gave nothing significant in favor of supplementing potassium permanganate with a hormone chemical (Fig. 8).

Cuttings from Ivory in February were used in another test. The cuttings were grown in sand for 19 days and rooting was classified into groups as good, poor, and not rooted. In a second test King Cardinal, Pelargonium, Wivelsfield Crimson, and Woburn were used and the results were recorded on March 7, 22 days after the cuttings were planted in the sand (Table 12).

Many tests have revealed the virtue of potassium permanganate in accelerating rooting and improving the growth of carnation cuttings in the propagating bench. The value of hormone substances for this purpose is recognized (38, 46). Either treatment is superior to none for promoting growth of roots. Nevertheless, most growers do not regard the hormone materials with favor except for varieties like Pelargonium that are hard to root, and prefer to root their cuttings in the natural way. Injury from the use of hormone materials has occurred frequently.

TABLE 12. EFFECT OF POTASSIUM PERMANGANATE AND HORMONE MATERIALS ON ROOTING OF CARNATION CUTTINGS.

Treatment (In the order used)	February 2-21			February 13-March 7		
	Percent Rooted		Percent Not Rooted	Percent Rooted		Percent Not Rooted
	Good	Poor		Good	Poor	
Potassium Permanganate 1-1,000	84	9	7	90.0	7.5	2.5
Potassium Permanganate, Rootone	67	29	4	90.0	7.5	2.5
Rootone	37	59	4	87.5	2.5	10.0
Rootone, Potassium Permanganate	80	13	7	85.0	5.0	10.0
Potassium Permanganate, Root-Gro				90.0		10.0
Root-Gro, Potassium Permanganate				100.0		
Potassium Permanganate, Hormodin A	90		10	90.0	5.0	5.0
Hormodin A, Potassium Permanganate	74	8	18	95.0		5.0
Hormodin A	75	13	12	97.5	2.5	
Potassium Permanganate, Auxilin	73	10	17			
Auxilin, Potassium Permanganate	72	11	17			
Auxilin	68	19	13			
No Treatment	59	35	6	42.5	25.0	32.5

The hormone treatment generally has not encouraged significantly better rooting than the permanganate treatment and the omission of the latter would be unwise if some degree of disinfection of the cuttings is desired. The treatment of the cuttings with both the hormone material and potassium permanganate in some instances gave superior results, irrespective of the order in which they were used; but the contrast between the dual treatment and potassium permanganate alone could not be considered sufficient to warrant the use of both in practice. The good results obtained from extensive tests with potassium permanganate alone warrant its use. If the grower will make fresh solutions every 7-10 days during the propagating season he will find much merit in its use in contrast to no treatment at all. The cuttings must not be rinsed after immersion in the solution; rather, they should be sprinkled overhead with water after they have been inserted in the sand.

PROPAGATION

The art of propagating carnations from cuttings has been described frequently in various bulletins on carnation culture and in the trade papers. The reader is referred to a recent and comprehensive account describing all the details of propagation by McCully (44), a commercial grower in Massachusetts.

Sanitation

The maintenance of sanitary conditions and good management of moisture and temperature conditions in the propagating house are highly desirable. Cleanliness and the sanitary disposal of carnation debris and unrooted litter are very helpful in disease control (Fig. 9). Beuerlein (4), a New Jersey commercial grower, emphasizes cleanliness in and around the greenhouse in view of the relationship of sick plants and carnation litter to the cultivation and spread of disease. This is especially applicable to the propagating house. The Botrytis

bud rot fungus, the various parasitic species of Fusarium, and the Alternaria blight fungus multiply on dead carnation debris.

In the preparation of the house for the new rooting season, all of the old sand is removed and the bare benches are washed clean with water. Some cautious growers drench the woodwork and ground with scalding hot water, or with a 1-75 solution of formaldehyde. The exposure of the bare wood to sun and drying weather before resanding is also desirable.

The presence of soil or organic matter in the sand could imply contamination with the Rhizoctonia stem rot fungus which inhabits all types of soil, even virgin soil. Tools should be cleaned before they are brought in contact with the sand, and every effort should be made to keep soil out of the propagating beds. The practice of transplanting the cuttings into soil in flats on the sand bench should not be tolerated.

Treatment of Sand

Frequently the same sand is used for rooting more than one crop of cuttings. Most growers use the sand but once and this precautionary practice is helpful in avoiding trouble, but there are times in the winter months when sand is difficult to obtain or to replace, and the grower is obliged to use the same sand again. Peltier (53) advocated treating the sand with steam and hot water. This practice would seem desirable especially for second cropping sand, to avoid disease which might originate from inoculum in the sand itself. Results reported by Kirby (36, 37) in Pennsylvania are strongly against the use of sand the second time without first sterilizing it. In an experiment reported by him 6 to 8 percent of the cuttings from new sand were infected with Alternaria in contrast to 56 percent from second-crop sand. The harvest of healthy well-rooted cuttings, rooting above 90 percent, should indicate that the same sand is safe for further planting. Nevertheless, commercial practice recognizes that rooting and disease control are improved by the use of new sand.

Some growers drench the sand with 1-1,000 solution of potassium permanganate previous to second use, and the practice is based chiefly on the faith in the chemical that some growers have acquired from its use as a disinfectant for cuttings. The results have been questionable in the absence of sufficient evidence and since the chemical is considered only mildly fungicidal. The results of a test with Virginia cuttings on new sand in March in a grower's propagating house where serious losses of cuttings from *Fusarium culmorum*, the root rot fungus, were occurring may be considered rather typical.

Treatment	Percent Well Rooted (Based on 140)
Potassium Permanganate	
(Cuttings)	96.5
(Sand)	95.3
(Cuttings and sand)	92.6
No Treatment	86.7

The results appeared to show that factors in the grower's practice, not revealed in this test, contributed to his loss. The value of propagating clean cuttings from clean sources was recognized and a greater improvement in the stand would appear to result from treating the cuttings rather than the sand with potassium permanganate. Potassium permanganate is not comparable in its fungicidal effect with the more generally recognized fungicidal chemicals, but it has a unique stimulating effect on rooting and is tolerated, which makes its use es-

pecially desirable. The management of the cutting bench with respect to watering, shade, light, and temperature is also of great importance to successful rooting and even more important than the quality of the sand used.

AGE OF PLANTS IN RELATION TO DISEASE AND YIELD

The relation of age of carnation plants to disease and yield of flowers during the first producing year has never been clearly established to the knowledge of the writer. Frequent observations have indicated more disease among the older plants, other conditions being alike. In New England new carnation plants are propagated from cuttings gathered from November to April, and all of the young plants propagated during these months are usually mixed together to constitute the next planting. By April all of the young stock is growing in pots or flats, and that of the earliest propagation has made the greatest growth of root and top. Early in the history of American carnation culture, rooting in February and March was apparently preferred. More recently, according to Wiggin (80), better results are secured from early propagation, i. e., November or December, because a larger plant with more branches is secured.

In transplanting operations and especially in transplanting from the field to the greenhouse benches, the greatest amount of breakage has appeared to occur among the largest or oldest plants. The close association of disease with injuries and unfavorable growing conditions has been established. Differences in yield of cut flowers of carnation plants made from cuttings taken in different months of the rooting season can be shown in some years. In the year 1931-32, Matchless carnations rooted in February and March yielded the greatest number of No. 1 flowers; December plants, the least. In the year 1932-33, February-rooted Matchless plants yielded slightly more No. 1 flowers than plants rooted in other months. In another year when only Matchless plants of January and March cuttings were compared for yield of cut flowers, there was no significant difference. In still another year, December-rooted plants yielded significantly more than plants rooted in January, February, or March, when all were benched on July 15. The March-rooted plants yielded the least. Factors other than the month of propagation appear to be involved.

FIELDING AND BENCHING

The maintenance of the producing stock in the greenhouse much after May 30 would require the fielding of the young plants, and it is also a factor in determining the date of benching. The two classes of stock are managed to correspond to each grower's concept of their respective value under his particular conditions. In the field the carnation stock experiences certain hazards from the weather and from disease, notably Alternaria blight, and a certain amount of abuse and injury in transplanting which also introduces a serious hazard from disease, notably Fusarium branch rot. Experience has taught that a long growing period in the field extending into late July and beyond is dangerous. In the shelter of the greenhouse many of the growth factors are under better control; but temperature conditions in the greenhouse in July and August can also be severe enough to check and suspend growth. Practice generally has taught the value of some outside growing and the importance of benching the stock early in the summer season. Delay in housing the fielded plants increases the amount of disease which can be shown in the yield of flowers (Fig. 10). A limited series of tests is suggestive of the idea.

Our experience in 1932-33 showed a much greater yield from January-rooted plants benched on July 20 than from similar plants benched on July 30. In the

same year March-propagated plants benched on July 10 and July 20 yielded the same; those benched on July 1 and June 20 increasingly less. In 1932-33 the effect of time of benching on yield of No. 1 Matchless carnations per square foot of growing area from October to February inclusive is shown in the following table.

	Benched on July 15	Benched on August 10
December Plants	15.0	5.1
January Plants	11.8	3.0
February Plants	13.5	7.1
March Plants	11.3	2.2

In 1936-37, housing on July 7 in contrast to September 4 increased the yield of No. 1 Boston Ward carnation flowers by approximately 42 percent. Early propagation plus late housing would appear to encourage more disease and a depreciation in growth and yield of flowers. If, under the grower's particular conditions, a limited period of outside culture is desirable, the plants should all be housed by the second week in July or even earlier. When Alternaria blight was first recognized as a serious carnation disease (14, 62, 81, 82), it was troublesome only on outside-grown plants. Where losses from blight have been repeatedly common, growers should abandon outside culture entirely.

CONTINUOUS GREENHOUSE CULTURE

Some of the young stock may be carried along in pots after rooting. This method of culture is desirable if the grower has sufficient help to give pot culture the care it requires. There are advantages, notably that less loss is encountered in transplanting and practically no injury. The shortage of labor and the added cost of culture would favor growing the young plants in 4-inch flats, and this is the common practice in New England. A limited stock may be carried along in greenhouse benches spaced 4 x 4 inches and transplanted later into permanent beds as the old producing stock is removed.

If the plants are not going into the field, they must be planted directly from the flats to the benches. While continuous inside growing contributes to the control of certain diseases, nevertheless it does not produce the kind of plant growth derived from a few weeks of outside culture. Since numerous factors are involved in determining the kind of growth under the two sets of conditions, it would not be fair to claim that one method is better than the other so far as flower production is concerned. The loss attendant upon one method might be turned into a gain by the advantage of some other contributing factor. Inside culture for the entire range would deprive some growers of a substantial income from the harvest of cut flowers in June and July, which other growers would regard as a false gain because of loss from disease resulting from the delay in replanting.

SEGREGATION OF YOUNG STOCK

Continuous inside culture raises the problem of plant growth control. The flats of soil planted to rooted cuttings are placed on supports above the flowering beds and along the eaves where growth conditions cannot be satisfactorily controlled and the detection of disease is obscured and delayed. The flats must be taken down in May, and sometimes it is a problem to decide how to handle the plants, especially when prices for carnations are high. Either the plants must be set in the field or in the benches, or they must be carried along in the flats

after May 30 until the old plants and soil can be cleaned out and the benches resoiled. Labor shortage requires planting the new stock in old soil, and the continuation of some of the flowering stock for two or even three years. The abuses which the young stock receives, and the loss attendant upon the delay would, in more normal times, justify a plant house wholly for growing the young plants (Fig. 11). A plant house should simplify the classification and segregation of the stock, make it easier to recognize disease and to exclude inferior or unhealthy stock from the planting, and enable the grower to realize more fully the potentialities of healthy, well-grown plants. It would eliminate much of the hard work of lifting the flats onto elevated supports and removing them again for planting.

GREENHOUSE MANAGEMENT

The intelligent management of the greenhouse atmosphere, and the judicious use of water, are intimately involved in the successful control of disease. During the course of these studies frequent instances of serious occurrences of the Alternaria blight disease were observed in places kept excessively wet by water dripping onto the planted beds through leaks in the greenhouse roof. The same condition may arise from careless watering practices and too much water.

Fusarium root rot, Fusarium branch rot, and Rhizoctonia stem rot are favored by high temperatures and a high water table. These diseases are epidemic only in the warmest months of the year.

The grower can encourage the prevalence of carnation foliage diseases in the greenhouse by tolerating continual moist and stagnant conditions. Exchanges of greenhouse air with the outside air are required to avoid, or to remove, moist stagnant atmospheric conditions. Both heating and ventilating require careful regulation to meet the changes created by the outside weather, and the effect of both upon the greenhouse atmosphere can be seriously impaired by the misuse of water.

Some growers believe that carnations do best by an alternate drying and wetting of the soil. Wiggin (80) states that carnations do best when the soil is uniformly moist but not saturated. It is his experience that newly benched plants should be kept as dry as possible without producing a wilted condition. Peltier (53) reported that the temperature should be kept as low as possible and no more water applied than is necessary for good plant growth.

Carnations are grown best at a temperature range of 50°–68° F. Low temperatures inhibit infection and the progress of disease, but they are difficult to maintain in Massachusetts greenhouses because of the warm weather prevailing in the first few months after the fielded plants are benched. Continued low temperatures correlated with a humid atmosphere encourage occurrence of Botrytis bud rot. These conditions are paired when heating is delayed or lacking in the fall months. An epidemic infection of the flowers by Alternaria in November and December, unusual as it is, occurs where both heat and ventilation are not properly managed. Similarly, the only devastating occurrence of *Heterosporium echinulatum* (Berk.) Cke., the fungus causing fairy ring spot, to come to the writer's attention was brought about by confined humid conditions and wet foliage. The same conditions apply to serious occurrences of carnation rust, *Uromyces caryophyllinus* (Schrank) Wint., and to bacterial leaf spot, *Phytomonas woodsii* (Smith) Bergey et al. These diseases become serious only as sound watering and management practices are seriously violated. In every instance the immediate correction of the contributing conditions has checked these diseases.

Figure 1. Alternaria Blight Infection of Carnation Foliage, Stems, and Flowers.

Figure 1. Alternaria Blight Infection of Carnation Foliage, Stems, and Flowers.

Figure 2. Carnation plants Infected with Alternaria Blight.
Showing the devastating effect of disease on the lower foliage while the plants were in the field, and the relatively healthy top foliage representing new growth in the greenhouse after the plants were benched.

Figure 3. Carnation Cuttings Showing Leaf and Stem Infections due to Alternaria Dianthi. Basal stem infections are frequently the cause of failure to root.

Figure 4. Single Spore Infections by Alternaria Blight Fungus, following inoculation of carnation plant with a water suspension of spores.

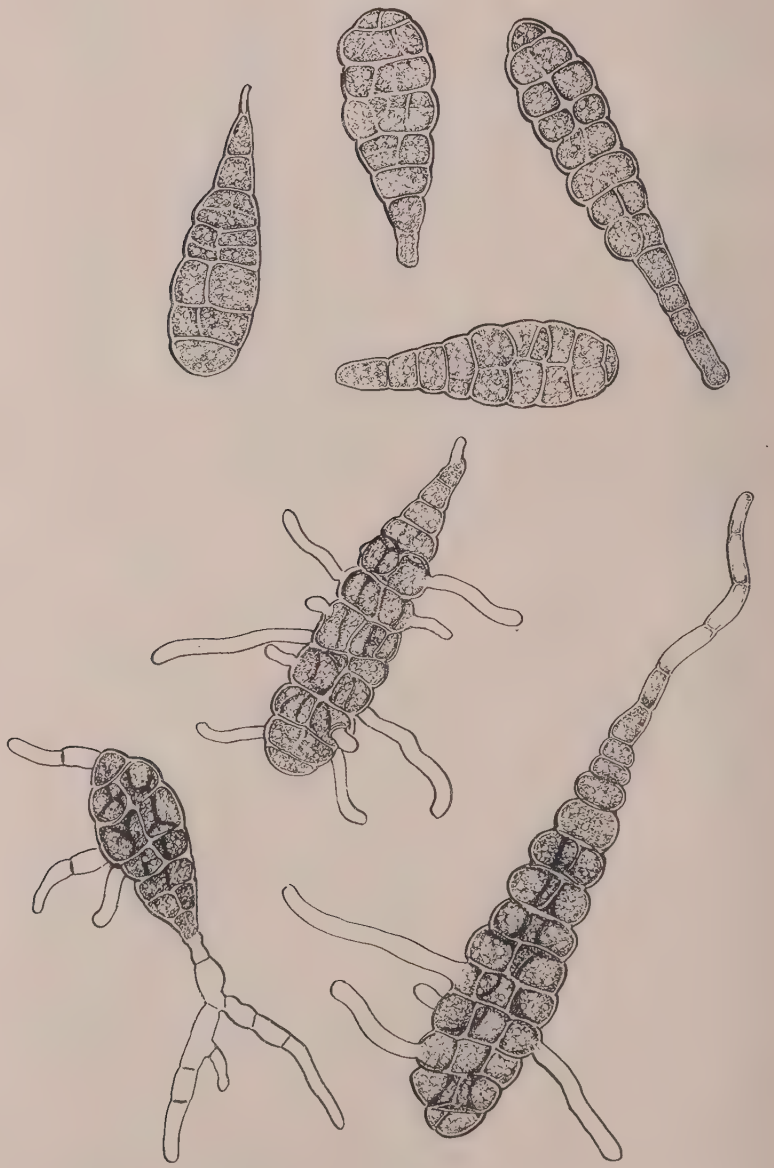


Figure 5. Conidia or Imperfect Spores of Alternaria dianthi; Germinating Spores.

Figure 6. Branch Rot caused by Fusarium dianthi.
Characterized first by wilting and rolling of a single branch and ultimately by the death of the entire plant.

Figure 7. Rhizoctonia solani, the Stem Rot Fungus, destroying Boston Ward plants growing in flats.

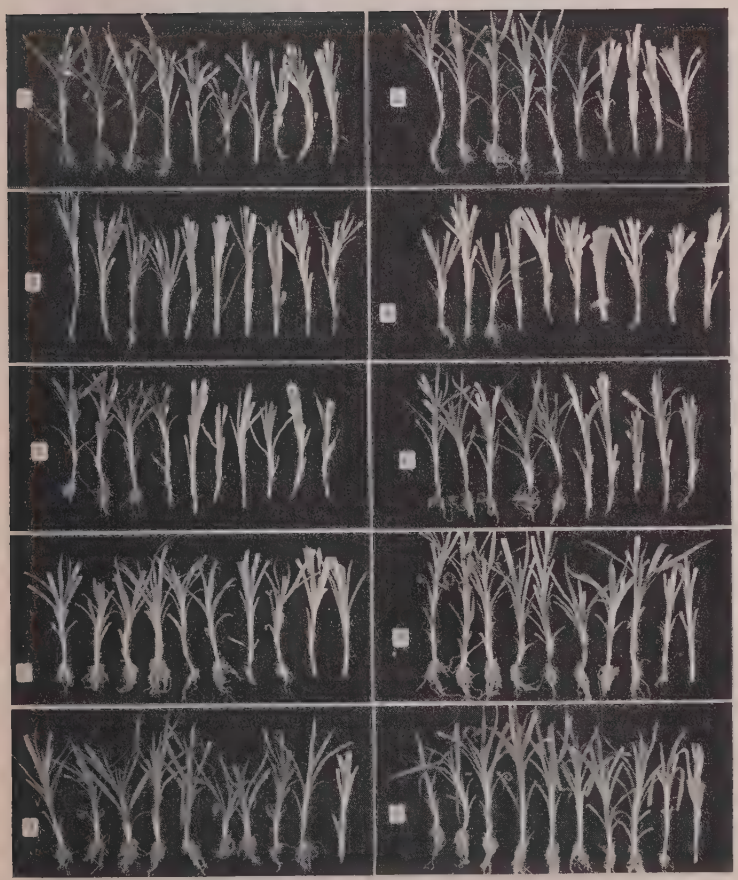


Figure 8. Carnation Cuttings Showing Contrasts in Rooting in Consequence of Treatments with Fungicidal Solutions and Root-Inducing Compounds.

1. Check—No Treatment
2. Thiourea
3. New Rootone
4. Old Rootone
5. Malachite Green 1-25,000, 15 min.
6. Methylene Blue 1-3,000, 15 min.
7. Potassium Permanganate + Old Rootone
8. Potassium Permanganate + Thiourea
9. Potassium Permanganate 1-1,000, 15 min.
10. Potassium Permanganate + New Rootone

Figure 9. Propagation House showing Sand Benches, with cloth curtain on the sides below to confine the heat underneath; cloth screens above to shade the rooting cuttings; ventilators for air exchange; thermometers for registering sand and air temperatures; and a particular regard for neatness and sanitation.

Figure 10. Two Benches in the Same Greenhouse, showing Contrasts in Growth of Carnations and Disease due to Alternaria dianthi.
Left: Transplanted from the field on July 15; Right: on August 20.

Figure 11. Greenhouse Devoted Exclusively to Young Stock.

Figure 12. Complete Susceptibility and Complete Resistance to Fusarium dianthi Exhibited by Virginia and Woburn Varieties, respectively.

Figure 13A. Olivette Carnations Transplanted June 1944 in Old Soil Used Once.
Above and below: Left bench, soil not steamed, transplanted from the field.
Right bench, soil steamed. transplanted from flats.
A. S. MacGuffog, Westboro, February 1945.

Figure 13B. King Cardinal Carnations Transplanted from Flats June 1944 in Old Soil Used Once.

Above: Left bench, soil steamed; Right bench, soil not steamed.
Below: Left bench, soil not steamed; Right bench, soil steamed.
Photographs taken from opposite ends of greenhouse. A. S. MacGuffog, Westboro, Feb. 1945.

Figure 14. Carnation Plants (Matchless), showing (above) Control of Blight from Spraying with Bordeaux, and (below) Not Sprayed

WATER SYRINGING AND NAPHTHALENE FUMIGATION

The substitution of naphthalene fumigation for the practice of syringing carnation plants with cold water or salt water to control red spider mite has improved the quality of carnations and aided in the control of disease (29). Two or three fumigations at intervals of 5 to 7 days are recommended, using naphthalene flakes at the rate of 2 ounces per 1,000 cubic feet, or a commercial naphthalene base fumigant as directed by the manufacturer. A temperature range of 70° to 80° F. and a relative humidity range of 60 to 80 percent should be maintained during the period of fumigation. One lamp is used for each 7,000 cubic feet, and the heat is adjusted to vaporize one-sixth of the dosage each hour of a 6-hour fumigation period. Fumigation should not be practiced during excessive wind or at temperatures above 90°.

Solutions of salt and nicotine sulfate in cold water, formerly used for syringing carnations, are not lethal to the red spider mite. Some fungicidal value is shown, and the spread of disease is indicated also. In one of the tests which is indicative, an average of 1.17 infections per leaf followed wetting the plants with a spore suspension of Alternaria in a 1-500 solution of 40 percent nicotine sulfate containing 5 percent table salt, in contrast to an average of 3.42 infections per leaf with a spore suspension in water.

Some experiments were carried out to determine the comparative effect of naphthalene fumigation and water syringing on the yield of flowers. The blight disease especially was a factor involved in the contrasts. Six benches in each of two adjoining like sections of a greenhouse of 5,000 cubic feet were planted to 54 Matchless plants each on August 1, 1929. The plants in the comparable benches were dug from the same plots in the field which, from June 21 to July 26 had been sprayed or dusted five times with fungicides. A spray of calcium arsenate and lime caused severe foliage injury and subsequently the plants became badly blighted. Plants treated with 20-80 monohydrated copper sulphate-lime dust were badly blighted and also infested with the red spider mite. Other plots of plants not receiving sulfur were more or less infested. After the plants were benched in the greenhouse, the red spider mite infestation was allowed to increase. One house was syringed regularly with cold water; the other fumigated with naphthalene. With the advance of the season distinct contrasts in growth and disease occurred in favor of fumigation, which are expressed in the yield of Number 1 flowers from October 1929, as follows:

Fungicide	Water Syringing	Naphthalene Fumigation	Percent Increase	Termination of Records
Dusts				
Sulfur	718	810	12.8	June 1
Monohydrated copper sulfate-lime 20-80	383	570	48.9	May 1
Sprays*				
Calcium Arsenate	63	123	95.2	January 1
Chemical Hydrated Lime 1½ lb.. Lime-Sulfur 1 gal.	532	763	43.3	June 1
Calcium Arsenate 1½ lb. Bordeaux 4-4-50	577	659	14.2	May 15
Calcium Arsenate 1½ lb. No Treatment	425	728	71.2	May 1

*Materials in 50 gallons.

A further test contrasting naphthalene fumigation and water syringing in adjoining greenhouse sections was conducted in 1930-1931. Each of the benches was planted to 54 Matchless plants grown from cuttings collected from Decem-

ber to March. The differences in the yield of Number 1 carnations from October 1930 to April 1931 inclusive are as follows:

Benching Date	Water Syringing	Naphthalene Fumigation	Percent Increase
May 1	99	311	214.1
July 1	215	568	164.1
July 15	243	396	62.9
August 15	145	159	9.6

More blight developed on the plants as the season advanced which, as might be expected, led to narrower differences in the yields of flowers between the two methods of red spider mite control.

The experiment was repeated in 1933-34. Matchless plants grown from December cuttings were planted June 9, 1933, in benches in each of two greenhouse compartments. The soil of one bench in each house was treated with hot water, the soil of another with 1-50 formaldehyde solution, and the soil of the third was left untreated. Naphthalene fumigation was practiced in one greenhouse compartment throughout the period of the test. In the other the plants were syringed with cold water. Satisfactory control of the red spider mite was not obtained with water, and in December 1933 the compartment was fumigated with naphthalene. The fumigation was repeated as necessary. The contrasts in yields of Number 1 carnations per square foot from October to March, 1934, inclusive, under the two sets of conditions are as follows:

Soil Treatment	Water Syringing	Naphthalene Fumigation	Percent Increase
Hot Water	8.1	10.2	43.6
Formaldehyde	8.6	11.0	27.9
No Treatment	5.6	7.5	33.9

Reviewing the results of the several experiments, the adverse effect of wetting the plants with water in the presence of Alternaria blight is shown in the yield of flowers. In the light of our knowledge of the influence of water on the development of other parasitic organisms attacking the foliage, a similar contrast might be shown in the presence of rust, bacterial spot, or fairy ring spot infection.

The warm temperatures required for naphthalene fumigation cause an acceleration of plant growth and also hasten the wilting symptoms of plants infected with Fusarium or Rhizoctonia. When wilting from such infections is present, more of it can follow under warm greenhouse temperature conditions.

Colonies of both Alternaria and Fusarium in nutrient agar culture plates were exposed in a house of carnations warmed for fumigation with naphthalene for 6 hours on each of 4 successive days in January. Both sets of culture plates were maintained for 4 more days in the greenhouse under conditions considered more nearly normal for carnations.

Average Diameter of Colonies Expressed in Millimeters

FUNGUS	CHECK		NAPHTHALENE	
	4 Days	8 Days	4 Days	8 Days
Fusarium culmorum	3.3	38	10	50
Fusarium dianthi	1.6	28	7	40
Alternaria dianthi	8.0	20	7.3	23

In another test over a period of 3 days in February with 6 hours of fumigation on each day, during which temperatures of 75°-80° F. prevailed in contrast to temperatures of 50°-55° in an adjoining greenhouse section, the difference in the average diameter in millimeters of the colonies on agar plates was as follows at the end of 3 days:

Fungus	Check	Naphthalene	Percent Increase
Fusarium culmorum	1.5	2.0	33.3
Fusarium dianthi	3.5	5.3	51.4
Alternaria dianthi	2.8	3.0	7.1

When the plants are generally healthy, none of these diseases become established under the conditions required for naphthalene fumigation. Spores of Alternaria and Fusarium were exposed for 3 days in February in a greenhouse section fumigated for 6 hours each day beginning at 10 a. m. No spore germination followed, whether the spores were exposed dry or previously sprayed with water. In the latter instance evaporation of moisture followed shortly after exposure. The concentration of naphthalene was not fungicidal. All of the evidence is clearly in favor of fumigation to control the red spider mite.

DISEASE RESISTANCE

No studies have been reported on the genetics of resistance to carnation wilt diseases and the development of disease-resistant types, although many investigators have speculated on the economic importance of such studies wholly on the basis of apparent differences in susceptibility of standard varieties to *Fusarium dianthi*.

Wight (79) advised, "grow resistant varieties" although none are defined. White (72) stated, "The most satisfactory solution of the wilt problem is offered in the possibility of the development of strains of plants immune or highly resistant to disease. There is no reason to doubt that resistant strains of the carnation could be obtained." Van der Bijl (67) stated: "The question of the existence of varieties more or less immune from disease has not received attention though a problem well worth serious consideration and the breeding of disease-resistant varieties may yet be the ultimate solution." Wickens (78) stated: "It is recommended that a search for resistance be made amongst the numerous seedlings raised by specialists in the development of new varieties and that the possibility of the occurrence of resistant sports in existing varieties be not overlooked."

Some conception of the task involved in the development of a commercially desirable type is conveyed by Weston (70): "Not only must the grower strive to grow quality blooms but he must select varieties that grow and produce well. They must have a reputation for giving a high average of good flowers; not be prone to splitting at the sight of dull weather; produce good stems that have some stamina in them; not be below average size and above all possess good color and be free from a tendency to go to sleep under normal conditions"; and by Laurie and Chadwick (40): "The ideal flower is of pleasing pure self color; non-bursting calyx; a diameter of 4 inches, erect wiry long stem; petals hard enough to withstand shipping; serrated, guard petals flat at right angles to calyx, center to stand above calyx one-half the distance to make half a sphere; fragrant, resistant to disease."

However, judging from the limited utility of new carnation varieties in commercial culture, it appears questionable whether the effort required to combine resistance with other desirable commercial qualities is justified. The variety or line of Mrs. C. W. Ward, from which by selection came Boston Ward and then New Deal Ward, although highly susceptible to Alternaria blight and Fusarium branch rot, has enjoyed the unique reputation of many years of utility. The introduction of this variety represented a great achievement. The desirable qualities of Boston Ward or any of its improved selections combined with resistance to *Fusarium dianthi* would appear to represent the nearest approach to the ideal pink variety.

TABLE 13. RELATIVE SUSCEPTIBILITY OF CARNATIONS TO ALTERNARIA DIANTHI.

Resistant		Slightly Susceptible	Very Susceptible
Abundance, Pink	Maine Sunshine	Atlantis	Aida
Achievement	Maytime	Donna Lee	Blush Pink
Antarctic	Melrose	Hazel Draper	Denver
Arctic	Morning Glow	Illuminator	Dorner's Surprise
Aviator	My Love	Jewel	Fairy Queen
Barbara Brigham	My Love, White	Luminosa	Gloria
Barbara Farr	North Star	Ocean Spray	Golden Glow
Beuerlein, Mrs. M.	Olivette	Scarlet Monarch	Guy Allwood
Bonanza	Orange Wonder	Spectrum	Hilda
Break-O-Day	Orchid Beauty	Spectrum, Salmon	Katrine
Chief Kokomo	Paragon	Spectrum Supreme	Laddie
Dairy Maid	Patrician		Marjorie
Dandy	Pelargonium	**Moderately Susceptible**	Matchless
Del Ray	Peter Fisher	Betty Lou	Matchless, Pink
Del Ray, White Sport	Pink Treasure	Delight, Pink	Multiflora
D mity	Po entate	Delight, White	Nina Brener
Ditchling	Puritan	Fragrance	Rosalind
Donald	Purity	Irene	Rose Charm
Early Dawn	Radiolite	Jane Sutherland	Royal
Early Rose	Satellite	Sceptre	Spicy White
Edna	Scarlet Monarch		Virginia
Eldora Variegated	Senator		Ward, Boston
Eleanor	Sim, Mary E.		Ward, Mrs. C. W.
Golden Wonder	Sophelia		Ward, New Deal
Great Heart	Snow White		Ward, Variegated
Harvester	Sunset Glow		Wardelia
Ivory	Super Supreme		
Joan Marie	Uneeda Pink		
John Briry	Wildfire		
Johnson's Crimson	Wilson, E. H.		
King Cardinal	Winsome		
	Woburn		

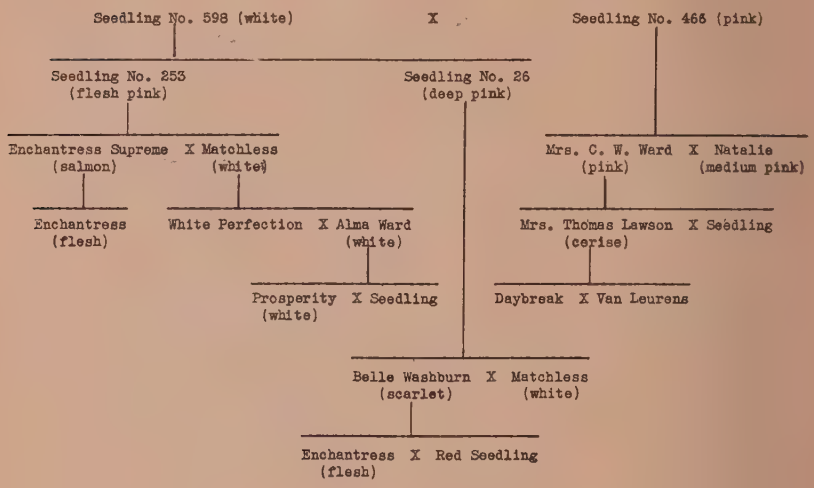
Alternaria Spot, Blight and Canker

The reaction to Alternaria blight of the many varieties of carnations current during the progress of these studies was determined from the amount of infection developing on the plants in the field. The contrasts in susceptibility were obtained by counting the number of infections on the stems, foliage, and floral parts of the flowering shoots which were harvested at regular, brief intervals up to early October and after the earliest frosts. Toward the end of the season the very susceptible varieties usually were destroyed by blight. Contrasts in the reaction of the varieties were shown by calculating the average number of infections per flowering shoot for each variety for the season and applying the number to a certain arbitrary range of infections per stem for each particular degree of susceptibility. The range for each classification necessarily was varied somewhat from year to year. The contrasts in the reaction of the varieties to Alternaria blight are purely relative and based on conditions in a limited geographical area. They are supported by extensive observations among plantings of growers and by the experience of growers in eastern New England over a period of several years. The varieties studied were limited to those current to the period from 1928-1940, most of which are now obsolete (Table 13).

The records of the pedigree of named carnation varieties are very incomplete and in many instances totally lacking. Too frequently varieties are announced as hybrids of unnamed seedlings. The earliest published accounts of carnation blight mention Enchantress and Mrs. Thomas Lawson as very susceptible. The

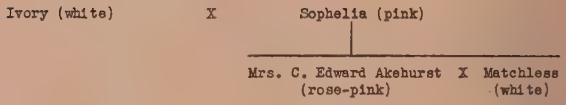
TABLE 14.—INCOMPLETE PEDIGREE OF SIX VARIETIES OF CARNATIONS RESISTANT TO ALTERNARIA DIANTHI.

1. IVORY (WHITE)


Seedling No. 598 (white) X Seedling No. 466 (pink)
Seedling No. 253 (flesh pink)
Seedling No. 26 (deep pink)
Enchantress Supreme (salmon) X Matchless (white)
Mrs. C. W. Ward (pink) X Natalie (medium pink)
Enchantress (flesh)
White Perfection X Alma Ward (white)
Mrs. Thomas Lawson (cerise) X Seedling
Prosperity (white) X Seedling
Daybreak X Van Leurens
Belle Washburn (scarlet) X Matchless (white)
Enchantress (flesh) X Red Seedling

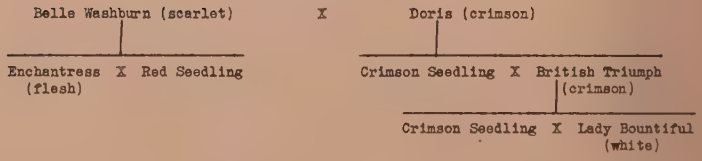
2. MAINE SUNSHINE (YELLOW)

3. PURITAN (WHITE)



4. PETER FISHER (PINK)

5. JOHNSON'S CRIMSON


Belle Washburn (scarlet) X Doris (crimson)
Enchantress (flesh) X Red Seedling
Crimson Seedling X British Triumph (crimson)
Crimson Seedling X Lady Bountiful (white)

6. SOPHELIA (PINK)

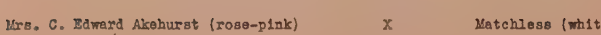


TABLE 15.—INCOMPLETE PEDIGREE OF SIX VARIETIES OF CARNATIONS VERY SUSCEPTIBLE TO ALTERNARIA DIANTHI.

1. MRS. C. W. WARD (PINK)

Mrs. Thomas W. Lawson (cerise) X Seedling

2. VIRGINIA (SHELL PINK)

Sceptre (salmon) X Boston Ward (medium pink)

Mrs. C. W. Ward (pink)

3. GOLDEN GLOW (VARIEGATED YELLOW)

Morning Glow (pink) X Matchless (white)

Winona (light pink) X The Queen (white)

William Scott (pink) X Daybreak (flesh)

4. WHITE CLOUD

Daybreak (flesh) X E. A. Wood (variegated pink)

Seedling X Tidal Wave (pink)

5. JANE SUTHERLAND (FLESH)

Prolific (shell pink) X Butterfly

Alice (shell pink) X Rosette (pink)

Mrs. C. W. Ward (pink) X Natalie (medium pink)

6. FAIRY QUEEN (FLESH)

Seedling No. 416 X Seedling No. 315

Seedling No. 10 X Alice (shell pink)

Seedling No. 1 X Seedling No. 261

Belle Washburn (scarlet) X Matchless (white)

Alice (shell pink) X Rosette (pink)

Enchantress Supreme (salmon) X Morning Glow (Var. yellow)

variety White Cloud was badly affected by the disease at South Bend, Indiana, in 1902. The parentage of Enchantress is unknown. Mrs. Thomas Lawson is a seedling of Daybreak X Van Leurens, neither of which can be traced further. White Cloud is a seedling of Daybreak X E. A. Wood, and the latter is a seedling of a cross of an unknown seedling X Tidal Wave. Tidal Wave is of unknown pedigree. Some of the more recent very susceptible varieties are Jane Sutherland, Golden Glow, Fairy Queen, and Virginia, and most of these are not too remotely descended from Mrs. Thomas Lawson. Golden Glow is a seedling of Morning Glow X Matchless, and the latter, like Boston Ward (selection of Mrs. C. W. Ward), is very susceptible to Alternaria blight. Matchless is a seedling of White Perfection X Alma Ward. The pedigree of White Perfection is unknown. Alma Ward is a seedling of Prosperity X an unknown seedling. The pedigree of Prosperity is unknown. With such incomplete records, it is not possible to trace the origin of susceptibility to a common ancestry.

In contrast, a high degree of resistance to Alternaria blight is shown by Ivory, Puritan, Peter Fisher, Maine Sunshine, Johnson's Crimson, and Sophelia. Sophelia, which is represented in the pedigree of many resistant varieties such as Joan Marie, Peter Fisher, and Puritan, is a seedling of Mrs. Akehurst X Matchless. The weakness of Matchless was its great susceptibility to Alternaria blight. Some of the pedigree of both Ivory and Maine Sunshine is Mrs. C. W. Ward, a very susceptible type.

It is interesting to note that named varieties originated as sports invariably possess the same reaction to disease manifested by their pedigree. For example, all of the selections and sports of Mrs. C. W. Ward are very susceptible to Alternaria blight. Sophelia has produced several sports, also Peter Fisher derived from Sophelia, all of which are highly resistant to blight.

Records of the pedigree, characters, and originator of carnation varieties have been maintained by the American Carnation Society since its inception at Philadelphia in 1891. It is regrettable that carnation breeders have in many cases failed to declare the pedigree of their named varieties and have disregarded the importance of the register in serving the useful purpose to science and the carnation industry for which it was originally intended.

The pedigree of twelve varieties of carnations has been traced as far back as possible from the Register of the American Carnation Society and from the notes of George Hetzel, breeder for C. B. Johnson, Woburn, Massachusetts, originators of several of the varieties for which histories are given. Tables 14, 15.

Carnation breeders have only rarely considered reaction to disease in the production of new varieties and it is, therefore, not surprising that this factor should have become understood only after the variety had been introduced to the trade. Consequently, many varieties have experienced only a limited commercial production and should never have been introduced. Of more than 100 new varieties of carnations introduced between 1930 and 1940, about 70 percent are resistant or only slightly susceptible to Alternaria blight and about 20 percent slightly to moderately susceptible.

Fusarium Root and Crown Rot

The reaction of carnation varieties to Fusarium root rot could not be established by submerging the roots in a water suspension of spores of *Fusarium culmorum*. Under commercial conditions of culture the disease has been troublesome on King Cardinal, Virginia, Olivette, and Boston Ward. All varieties show susceptibility when the fungus inoculum is placed into knife cuts in the stems of branches and swabbed with moist cotton. Studies at the Colorado Agricultural Experiment Station (15) have not revealed any resistant types among *Dianthus*

caryophyllus L. although other Dianthus species, not named, are reported to be quite resistant. Numerous species of Fusarium, further divisible into several strains, exist to complicate the problem. The disease appears almost always in devastating proportions in commercial houses in the summer months under the influence of conditions not easily duplicated in experimental trials. Propagation from diseased stock plants definitely causes the continuity of the disease.

Fusarium Branch Rot

Bickerton (5) stated that resistant varieties should be grown in preference to the more susceptible kinds. He determined the degree of susceptibility of 10 varieties of carnations to *Fusarium dianthi* from field observations and root inoculation studies as follows:

SLIGHT	MODERATE	SEVERE
King Cardinal	Sophelia	Chief Kokomo
Maine Sunshine	Virginia	My Love
Patrician		Spectrum Supreme
Peter Fisher		
Puritan		

The reaction of many varieties to the fungus was determined by the same method; namely, dipping the rooted base of carnation cuttings as they are taken from the sand in sterile water containing pure culture inoculum of the fungus and then growing the plants in steam-sterilized soil. Extreme reactions to the fungus were manifested by different varieties, as, for example:

VERY RESISTANT	VERY SUSCEPTIBLE
Dorothy Napier	Barbara Brigham
Eleanor	Joan Marie
Elizabeth Rowe	Marchioness of Headfort
Georgina	Mary Stuart
Hazel Draper	New Deal Ward
Helen Hussey	Nina Brener
John Briry	Northland
Maine Sunshine	Pelargonium
Miller's Yellow	Peter Fisher (regular)
Mrs. C. B. Johnson	Pink Lady (Virginia Rose)
Puritan	Pink Treasure
Tom Knipe	Rosalie
Woburn (Figure 12)	Scarlet King
	Spectrum Supreme
	Virginia (regular) (Figure 12)
	Wildfire

In general, these varieties show a similar performance in commercial culture.

Further study is required to determine more definitely the susceptibility of the varieties to branch rot under variable conditions. Disagreement with the results reported by others might readily be due to the influence of variable genetic strains of the fungus. The analysis and segregation of the progeny resulting from selfing and hybridizing very resistant carnations and the development of commercially desirable types resistant to the branch rot fungus represent a promising field of study.

Rhizoctonia Stem Rot

No resistance to *Rhizoctonia solani* has been established.

SOIL STERILIZATION

As early as 1897 Sturgis (65) considered that the disinfestation of the soil with heat contributed to the control of Fusarium branch rot of carnations, but his results were negative in view of complications arising from infection inherent in the cuttings. Ward (68) advised the sterilization of the sand in the propagating house and the soil in the benches and the selection of a new field. Van der Bijl (67) reported no beneficial effect from treating the soil with formaldehyde, and did not consider soil sterilization practical under the method of culture peculiar to South Africa.

Peltier (53) reported that formaldehyde used as a soil disinfestant to control Rhizoctonia stem rot was but a partial success, the losses varying from 24 to 53 percent. Steaming the bench soil controlled the disease when the soil was artificially infested, but no losses occurred in the uninoculated and unsterilized sections. The production and quality of the flowers were not affected by heating the soil, nor were they consistently improved. Weinard and Decker (69) found that the loss of plants from Rhizoctonia stem rot in old soils averaged about 4 percent compared with about 3 percent in new soil. The loss of plants on new steamed soil was about 6 percent; on new unsteamed soil about 5 percent. The loss on soil cropped for two years and steamed was about the same as on the same soil unsteamed, or about 6 percent. After 15 years of steaming, 2 percent of the plants were lost compared with 9 percent on the unsteamed plots. It was not surprising to them that steaming the bench soil did not eliminate the stem rot disease since soil was brought from the field on the plants. However, their work showed that soil treated with steam year after year could be kept in a highly productive condition indefinitely and the yield and quality of the flowers greatly improved.

Wickens (78) considered steaming the soil not an adequate control measure for Verticillium carnation wilt in England. Steamed soil sometimes showed greater losses than unsteamed, since cuttings from apparently healthy plants are frequently infected and give rise to diseased plants. Steam sterilization of the soil has met with numerous failures in England (Brown 10). Soil steaming in relation to the control of Verticillium wilt is often discredited from the frequent failure of treated beds to remain free from disease for the complete period of the crop or throughout the second year (White 76). Brown (9) considered heat sterilization of the soil effective, and formaldehyde 1-50 the best chemical. The beneficial effect measured by the survival of the plants was comparable to that of replacing the top soil with clean soil.

White (71) considered the development and extension of soil sterilization essential to the control of Fusarium wilt diseases in carnation nurseries in England. Dowson (4) contended that the control of Fusarium wilt is best accomplished by soil steaming and the growing of healthy plants, although no supporting experiments are shown.

Bickerton (5) reported appreciable control of Fusarium branch rot from the treatment of the field and bench soil with either chlorpicrin or formaldehyde or from the treatment of the bench soil alone with chlorpicrin well in advance of planting. The treatment of the bench soil with chlorpicrin gave a significant increase in flower production even though the plants had previously been grown in infested soil. The value of treating the old soil in lieu of changing was clearly shown.

Most of the New England carnation growers have conducted limited demonstrations with chlorpicrin. Portions of the greenhouse beds were injected with chlorpicrin at the rate of 2 cc. per square foot, well in advance of benching outside-grown plants. In most cases differences in favor of the treated soil were not apparent, but in some cases the differences have been rather striking. Charles Rice of Lexington obtained differences in the yield of carnations on old and new soil treated with chlorpicrin applied in June before planting from the field, and contrasts undoubtedly could have been shown in many of the other demonstrations if the results had been measured in a similar manner, or if the ideal soil conditions necessary to the efficiency of the treatment had existed at the time of application. Some of these are (1) a loose permeable soil, (2) a relatively dry soil holding only enough moisture to partially hold its shape when squeezed in the hand, (3) a soil temperature warmer than 65° F., and (4) a seal of moist soil on the surface, or a cover of paper or burlap for a few days after application, to confine the gas.

The bench plots in the Rice experiments comprised 65 square feet each. The yield of flowers was recorded throughout the year. The gain of flowers indicated in Table 16 represents the difference between the production on new untreated

TABLE 16. AVERAGE YIELD OF CARNATION FLOWERS PER SQUARE FOOT. OLD AND NEW BENCH SOIL TREATED WITH CHLORPICRIN. Charles Rice, Lexington.

Variety	Plot	Yield per Square Foot		Variety	Plot	Yield per Square Foot	
		September to June 1941-42	September to May 1942-43			September to May 1942-43	November to May 1942-43
Puritan	1-0	39.5	32.2	John Briry	1-0	18.2	
	1-1	41.3	33.4		1-1	19.7	
	2-2	41.7	32.6		2-2	19.0	
	3-2	41.0			3-3	19.0	
	3-3		32.7		4-3	17.9	
	4-3		31.2	Gain over	1-0	0.7	
Gain over	1-0	1.8	0.2				
King Cardinal	1-0	30.0	22.7	Pelargonium	1-0	18.9	
	1-1	31.7	23.5		1-1	20.2	
	2-2	30.9	23.4		2-2	19.1	
	3-2	30.7			3-3	21.0	
	3-3		24.0		4-3	19.0	
	4-3		24.1	Gain over	1-0	0.9	
Gain over	1-0	1.1	1.0				
Boston Ward	1-0	37.4	21.0	Olivette	1-0	20.9	17.1
	1-1	41.9	21.8		1-1	22.2	18.6
	2-2	42.5	21.6		2-2	21.0	17.7
	3-2	41.3			3-3	20.7	17.7
	3-3		22.7		4-3	20.5	17.4
	4-3		22.6	Gain over	1-0	0.2	0.7
Gain over	1-0	4.5	1.1				
					2-0		16.5
Virginia	1-0	32.9		Gain over	2-0		1.3*
	1-1	35.1					
	2-2	37.6					
	3-2	36.0					
Gain over	1-0	3.3					

1-0 New Soil, first year of use, not treated
1-1 New Soil, first year of use, first treatment with chlorpicrin
2-0 Old Soil, second year of use, not treated
2-2 Old Soil, second year of use, second treatment with chlorpicrin
3-2 Old Soil, third year of use, second treatment with chlorpicrin
3-3 Old Soil, third year of use, third treatment with chlorpicrin
4-3 Old Soil, fourth year of use, third treatment with chlorpicrin

*Difference between the yield of flowers from untreated soil the second year of use and the average of the yields from the treated plots. The 2-0 plot did not begin to produce flowers until November; hence the November to May production of the other plots is given for comparison.

soil and the average of the production on treated soil. In the year 1941-42 the contrast was significant only among Boston Ward and Virginia varieties, which are very susceptible to all of the wilt diseases. For Virginia the difference was 3.3 flowers per square foot in favor of the treated soil; for Boston Ward, 4.5 flowers. These increases represented a gain of $0.13 and $0.18 per square foot, estimating the value of the flowers at $0.04 each. The other varieties showed smaller contrasts in yield in a range of 1.1 and 1.8 flowers per square foot, or a gross gain of $0.044 to $0.072. With a single exception similar gains are shown between new untreated soil and new treated soil. After deducting $0.01, representing the cost per square foot for material and labor, the gain appears to be worth the effort.

The old producing plants were removed in June, 1942. Two inches of soil in the benches were removed and two inches of cow manure added. Also 4 pounds of bone meal and 2 pounds of 4-12-4 fertilizer were added to each 100 square feet of bench space. Chlorpicrin was again applied at the rate of 2 cc. per square foot.

The contrasts in the yield of cut flowers in the production year of 1942-43 (Table 16) are not significant. The official report of the New England Carnation Growers Association shows that production during 1942-43 was 18 percent below that of the year 1941-42. This drop, and the fact that no flowers were cut in June, accounted for the drop in production from the previous year.

The treatment of the old soil with chlorpicrin increased the yield of flowers only slightly. The difference between the number of flowers from untreated new soil and the average from the treated soil ranged from 0.2 to 1.1 flowers per square foot, representing a gross gain of $0.008 to $0.04. A gain of 1.3 flowers or $0.05 is shown by Olivette, based on the yields on untreated soil the second year of use and on treated soil. After a deduction of $0.01 for costs, the investment appeared to be of doubtful value.

Bickerton (5) reported a net profit of $0.23 to $0.38 per square foot from the treatment of the bench soil with chlorpicrin, and on this basis it was asserted that the treatment would appear to solve the problem of low and decreasing yields of flowers on the same soil used again.

Some growers from custom have preferred steaming, and this, in the judgment of New England carnation growers, is the most popular method. Disinfestation of soil for growing the young stock plants is generally practiced and various ways of steaming the soil are also practiced. Resoiling the benches at the end of the growing season is one of the most costly operations in carnation culture. With serious shortages in man power, the continued maintenance of the old soil in a sanitary and highly productive state by any combination of sterilization and fertilization instead of replacement is highly desirable.

The various reports on the value of soil sterilization in relation to the control of carnation wilt diseases and flower production are not entirely favorable. Examples of bench soil sterilization with steam have been observed in many growers' establishments, but the apparent effect on disease control and growth frequently has been either lacking or inconsistent. Even in instances where disease is prevalent year after year, and where soil sterilization would appear to be desirable, no apparent improvement is shown. In an open discussion on the subject on soil sterilization by experienced and capable New England carnation growers no conclusive evidence of disease control from treating the soil was admitted.* Nevertheless, striking contrasts showing the value of treating old or used soil with steam or chlorpicrin are sometimes apparent (Fig. 13).

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*Reported by K. F. McCully, Secretary-Treasurer, New England Carnation Growers Association, in Florists' Review 94 (2426) : 19. May 25, 1944.

Occurrences of carnation wilt diseases are intimately associated with high temperatures, excessively wet soil, inadequate drainage, plant injuries, deep planting, faulty propagation, and infected cuttings. For example, the culture of carnations in raised beds, in contrast to ground beds, has resulted in much better control of the wilt diseases. Soil contamination exists generally where carnations are grown under glass, but it appears to become a factor in the occurrence of disease only when sound cultural and propagating methods are seriously violated.

CONTROL OF ALTERNARIA BLIGHT WITH FUNGICIDES

In general, foliage diseases of economic plants due to Alternaria and closely related pathogenic fungi have yielded to control from protective spraying with copper fungicides. Woods (81, 82) and others (14, 62, 63), in the first published accounts of the disease, suggested spraying the plants with soap and Bordeaux mixture from the time they are fielded in the spring to the time they are well established again in the benches. Over the years since 1927, the writer has advocated spraying the fielded plants with Bordeaux mixture and spreader (28, 29, 30, 31, 32, 33). This treatment was recommended on the basis of fundamental studies and control experiments in the field (Fig. 14) which are reported here for the first time. In the interval, Bickerton (6), working on Long Island, New York, demonstrated the value of field spraying and showed both a significant reduction in infection and a significant increase in production. Other workers and growers, without showing detailed results in support of spraying, have recommended it as a proper treatment for the control of blight.

Toxicity of Chemicals to Conidia

Conidia of the fungus, *Alternaria dianthi* were readily obtained from blighted carnation leaves. Four techniques were followed in determining the toxic effect of the chemicals used: (1) Dry spores were gathered from diseased leaves with a camel's-hair brush and deposited upon the dry chemical residues on glass slides; (2) the spores were first deposited on glass slides and subsequently the fungicide was atomized or dusted upon the spore-bearing surface and the spray allowed to dry, before the slides were placed in a damp chamber for spore germination; (3) the spore-bearing slides were sprayed and immediately placed in moist dishes, and the moist film on the spore-bearing surface was maintained throughout the incubating period; (4) the slides were first sprayed or dusted with chemicals, the sprayed slides were air-dried, and drops of water suspension of spores were then applied to the dry residue.

As may be observed from Table 17, the procedure used has a bearing on the action of the chemical. The presence of water in some instances rendered the chemical deposit soluble, thereby destroying the viability of the spores. This is notably true of the treatments containing copper or calcium arsenate. Spores deposited in the dry residue and in a moist atmosphere germinated; those in the residue in water or in a moist film were killed. Sulfur dust was not fungicidal, and liquid lime sulfur concentrate 1-40 was fungicidal only when the spores were wetted by the spray, suggesting the limited value of lime sulfur as a disinfectant. When a water suspension of spores or dry spores were placed on the dry residue of lime sulfur, spore germination was not destroyed, indicating that the residue after spraying offers no protection against infection. The same might be inferred from the results obtained with a 1-200 solution of potassium sulfide. Lead arsenate was not toxic. Lime was not toxic. All of the dry dust mixtures containing naphthalene were fungicidal under each of the four methods of test-

ing, the toxic action being due to the naphthalene component of the dust mixture. Without moisture on the spore-bearing surface, no effect from copper or calcium arsenate in the confined atmosphere of a Petri dish was shown. In the presence of moisture, naphthalene, copper sulfate, or calcium arsenate exerted a lethal effect upon the spores. The results corroborate the evidence of other investigators claiming the strong fungicidal action of calcium arsenate. The concentration of naphthalene vapor in the small and confined atmosphere of a Petri dish was derived from mixtures containing 30 percent naphthalene. Weaker concentrations might have been adequate. A spray containing 1.6 pints of 40 percent nicotine sulfate (.2 percent) and 40 pounds of salt in 100 gallons of water (5 percent) was not significantly toxic.

TABLE 17. TOXICITY OF FUNGICIDES TO SPORES OF ALTERNARIA DIANTHI.

Fungicide	Dry Spores Applied to Dry Residue (1)	Dry Spores Treated with Fungicide		Water Suspension of Spores Applied to Dry Residue (4)
		Incubated Dry (2)	Incubated Wet (3)	
Dusts[1]				
Sulfur	+	+	+	+
Copper[2] 20, Lime 80	+	+	−	−
Naphthalene 30, Lime 70	−	−	−	−
Naphthalene 30, Sulfur 20, Copper-Lime 50	−	−	−	−
Naphthalene 30, Calcium Arsenate 20, Copper-Lime 0	−	−	−	−
Naphthalene 30, Calcium Arsenate 20, Sulfur 50	−	−	−	−
Sprays[3]				
Hammond's Copper Solution (1-50)	+	+ *	−	−
Potassium Sulfide (1-200)	+ *	−	−	+
Lime-Sulfur (1-40)	+	−	−	+
Bordeaux (4-4-50)	+	+ *	−	−
Lead Arsenate (2 lb.-50 gal.)	+	+	+	+
Calcium Arsenate (2 lb.-50 gal.)	+	+ *	−	−
Calcium Arsenate 2 lb., Lime 2 lb.-50 gal.	+	+ *	−	−
No Treatment (Water)	+	+	+	+

\+ Germination. − No Germination. * Germination considerably inhibited.

[1]Figures indicate weight in pounds

[2]Copper in dust mixture derived from monohydrated copper sulfate.

[3]Figures indicate gallons unless otherwise specified.

Laboratory Experiments

Two potted carnation plants of the Jewel variety were used for each treatment. The fungicides were applied on January 9 and the plants were sprayed with a water suspension of spores on January 10. The results were recorded on February 12, 1929 (Table 18). The results were clearly in favor of calcium arsenate and Bordeaux mixture, and each of these materials was more effective in combination with fish oil than alone. Sulfur materials gave poor control. In another experiment with the same variety, Jewel, infections were evident January 27 and the results were recorded on February 11 (Table 19). Bordeaux mixture and calcium arsenate again showed superior fungicidal efficiency. No benefit was shown from the addition of saponin as a spreader.

TABLE 18. CONTROL OF ALTERNARIA INFECTION ON POTTED JEWEL CARNATIONS.

Fungicide*	Number of Leaves	Percent of Infected Leaves	Number of Infections
Calcium Arsenate 1½ lb.-50 gal.	35	45	22
Same, plus Fish Oil ½ pt.	35	17	11
Bordeaux 4-4-50	40	55	27
Same, plus Fish Oil ½ pt.	36	13	5
Lime-Sulfur 1 gal.-40 gal.	28	78	57
Same, plus Fish Oil ½ pt.	27	85	62
Potassium Sulfide 2 gal. -50 gal.	34	82	81
Same, plus Fish Oil ½ pt.	39	89	88
Ammonia 3 pt., Copper Carbonate 6 oz.-50 gal.	28	53	31
Same, plus Fish Oil ½ pt.	31	51	34
No treatment	38	79	101

*Fish oil was added to improve wetting.

TABLE 19. CONTROL OF ALTERNARIA INFECTION ON POTTED JEWEL CARNATIONS.

Fungicide*	Number of Leaves	Percent of Infected Leaves	Number of Infections
Calcium Arsenate 2 lb.-50 gal.	28	7	3
Same, plus Saponin 2/3 oz.	28	14	4
Lead Arsenate 2 lb.-50 gal.	32	81	61
Same, plus Saponin 2/3 oz.	30	80	88
Bordeaux 4-4-50	31	13	4
Bordeaux, Calcium Arsenate	30	10	3
Bordeaux, Lead Arsenate	28	10	3
No Treatment	32	72	140

*Saponin was added to improve wetting.

Dust mixtures of calcium arsenate, lime, sulfur, monohydrated copper sulfate, and powdered naphthalene were compared for their effect upon the control of the disease. Carnation plants, Variety No. 724, were dusted with the following mixtures:

Dust Materials — Parts by Weight

Sulfur
Monohydrated Copper Sulfate 20, Lime 80
Naphthalene 30, Lime 70
**Naphthalene 30, Calcium Arsenate 20, Sulfur 50
*Naphthalene 30, Calcium Arsenate 20, Monohydrated Copper Sulfate – Lime 50
Naphthalene 30, Sulfur 20, Monohydrated Copper Sulfate – Lime 50

The mixtures containing calcium arsenate (marked by asterisks) gave excellent protection against infection, but the mixture indicated by the double asterisk caused injury. The effective ingredient appears to be calcium arsenate, and the importance of adding lime to dust mixtures containing calcium arsenate to avoid injury is indicated by these results and other experience. The copper and sulfur dusts used were not effective.

The results from these exploratory studies on the value of chemical sprays and dusts for controlling the disease on plants in damp chambers provided the basis for further and greater effort in the field under natural conditions of inoculation.

Field Experiments

Thirteen fungicidal treatments were compared in the field in the 1929 experiments on Jewel and Matchless carnations. Ten applications were made, the first on June 21 and the last on September 29. Alternaria blight appeared early in July but the disease did not become serious until September. A record of the prevalence of the disease in the treated plots was made on July 20 prior to transplanting into the greenhouse benches. Calcium arsenate alone or in combination with lime sulfur caused injury which was subsequently followed by more infection. Bordeaux with calcium arsenate was not injurious. A heavy infestation of red spider mite developed on the plants treated with copper-lime dust, and subsequently these plants also became badly infected with blight. Injury from spraying and from the red spider mite clearly disposed the plants to more disease. Unsprayed and uninjured plants showed an insignificant amount of disease in 1929 up to July 30 (Table 20). The remaining plants in the plots in the field continued to receive the fungicidal treatments, and the amount of disease was determined by counting the infections on the cut flowers harvested from September 14 to October 5, The best control was obtained with Bordeaux mixture combined with calcium arsenate; with Bordeaux mixture and fish oil; and with Bordeaux mixture plus calcium arsenate and fish oil. Control was relatively poor with Bordeaux without the fish oil. The greatest amount of

TABLE 20. CONTROL OF ALTERNARIA CARNATION BLIGHT IN THE FIELD. JEWEL AND MATCHLESS VARIETIES. WALTHAM, 1929.

Fungicide[1]	Number of Infections		
	Per Plant on July 30	Per 100 Stems	
		Sept. 14-Oct. 5	Oct. 28
Dusts			
Sulfur	0.39	131	406
Copper-Lime 20-80	0.69*	318	1,931
Sprays			
Hammond's Copper Solution 1 gal.-50 gal.	0.04	136	364
Potassium Sulfide 1½ gal.-50 gal.	0.05	195	442
Lime-Sulfur 1 gal.-50 gal.	0.02	184	304
Calcium Arsenate 1½ lb.-50 gal.	1.66**	850	1,052
Bordeaux 4-4-50	0.12	142	287
Same, plus Fish Oil ½ pt.	0.01	53	167
Bordeaux, Calcium Arsenate	0.00	63	162
Same, plus Fish Oil ½ pt.	0.02	54	129
Lime-Sulfur, Calcium Arsenate	0.43***	142	152
Same, plus Fish Oil ½ pt.	0.72***	164	197
No Treatment	0.04	519	1,056

[1]Fish Oil was added to improve wetting.

* Heavy infestation of red spider mite.
** Severe injury; fungus secondary.
*** Injury prevalent; fungus secondary.

disease was associated with the use of calcium arsenate, which was injurious by itself; with copper-lime dust, where a serious infestation of red spider mite developed; and with no treatment.[4] On October 28, one month after the last fungicidal application, the final harvest of flowering stems of Matchless carnations was made and checked for the total number of Alternaria infections. The addition of calcium arsenate to lime sulfur or Bordeaux improved the control of blight considerably. Except for injury associated with the use of combined lime sulfur and calcium arsenate, the control of infection compared favorably with that obtained with the Bordeaux-calcium arsenate combinations.

In the summer of 1930, ten materials were compared on plots of 80 plants each, as follows:

Dust Materials — Parts by Weight

Calcium Arsenate 20, Lime 80
Monohydrated Copper Sulfate 30, Lime 70
Calcium Arsenate 15, Monohydrated Copper Sulfate 15, Lime 70
Naphthalene 20, Calcium Arsenate 20, Lime 60
Naphthalene 20, Calcium Arsenate 15, Monohydrated Copper Sulfate 15, Lime 50
Naphthalene 20, Sulfur 15, Monohydrated Copper Sulfate 15, Lime 50

Spray Materials — In 50 Gallons of Water

Hammond's Copper Solution 1 pint
Fungtrogen 3 pints
*Copper Sulfate 2 lb., Sal Soda 3 lb., Fish Oil ½ pint
*Copper Sulfate 2 lb., Caustic Soda 1 lb., Fish Oil ½ pint

Ten applications were made, the first on June 13 and the last on August 22. The disease was observed generally among the plants in the week of June 9. The first application seemed too late, and weather conditions were very favorable for blight. Only Sal Soda Bordeaux and Caustic Soda Bordeaux (indicated by an asterisk) gave satisfactory control of the disease. The results showed the difficulty of controlling the disease in the field in seasons marked by moisture conditions favorable to the fungus.

In the season of 1931, fourteen treatments were compared on Matchless carnations, as follows:

Dust Materials — Parts by Weight

Calcium Arsenate 15, Monohydrated Copper Sulfate 15, Lime 70
Naphthalene 20, Calcium Arsenate 15, Monohydrated Copper Sulfate 15, Lime 50
Naphthalene 20, Sulfur 15, Monohydrated Copper Sulfate 15, Lime 50
Naphthalene 20, Calcium Arsenate 20, Lime 60

Spray Materials — In 50 Gallons of Water

*Bordeaux 4-4-50, Calcium Arsenate 1 lb., Fish Oil ½ pint
*Bordeaux 4-4-50, Calcium Arsenate 1 lb.
*Bordeaux 4-4-50, Fish Oil ½ pint
*Bordeaux 4-4-50
'Bordow 8 lb., Fish Oil ½ pint
Bordow 8 lb.
Lime Sulfur 1 gal., Fish Oil ½ pint
Lime Sulfur 1 gal.
Dry Lime Sulfur 4 lb., Fish Oil ½ pint
Dry Lime Sulfur 4 lb.

[1]Dow Chemical Company; not more than 13 percent metallic copper.

The individual plots consisted of 90 plants arranged in 6 rows of 15 plants each. Seven applications were made, the first on June 2 and the last on August 20. The flowering stems were gathered as they blossomed from August 7 to September 20, and the number of infections was recorded at each harvest. Satisfactory control of the disease was obtained only with Bordeaux mixture sprays. Sulfur sprays and all of the dust mixtures gave poor control. Improvement in the control of blight was shown by the addition of calcium arsenate and fish oil to homemade Bordeaux mixture.

In the summer of 1932, further comparisons of fungicidal sprays were made in the field. Six applications were made, the first on June 10 and the last on August 8. The value of the treatments was determined by the counts of the number of infections on the flowering stems gathered over the period from August 15 to September 13. The control of the disease was best with Bordeaux 4-4-50, calcium arsenate 1 pound, and fish oil ½ pint; and plants receiving the Bordeaux combinations appeared greener and relatively healthy throughout the season. Plants from the plots sprayed with combined Bordeaux, calcium arsenate, and fish oil were benched on August 10 after the last field application, and two additional applications were made on a portion of the benched plants. Yield records were taken from October to May and comparisons were made with the yield of plants never sprayed, either in the field or bench. The yield of flowers of the plants sprayed in the field was twice that of the unsprayed plants, and no increase over field spraying was shown by the plants sprayed twice more in the benches.

In 1936, at Waltham and Lexington, comparisons were made between no treatment and combined Bordeaux 4-4-50, calcium arsenate 1 pound, and fish oil ½ pint. The Matchless and Boston Ward varieties were grown in both tests. No perceptible injury from spraying was present. At Lexington there were 405 plants in each plot and the flowering stems were gathered for infection counts from September 22 to October 9. At Waltham infection counts were made from August 17 to September 1. Results of the two experiments were as follows:

Treatment	Number of Infections per 100 stems	
	Lexington	Waltham
Sprayed	5.1	9.8
Unsprayed	255.6	155.0

At Waltham, plants from the sprayed and unsprayed plots were benched on July 7 and September 4. There was no significant improvement in the yield of No. 1 carnations per plant from October 1936 to May 1937, inclusive, in favor of spraying in the summer of 1936; but the contrasts in yield of flowers resulting from early and late housing are especially significant.

Treatment	Benched July 7	Benched September 4
Sprayed	9.7	6.1
Unsprayed	9.6	5.1

In the summer of 1940, plots of the variety Nina Brener were sprayed periodically in the field, and 140 plants from each plot were planted in 48 square foot benches in the greenhouse in July. An additional application was made after the plants were established in the benches. The superior fungicidal effect of Bordeaux with calcium arsenate has been indicated, and a knowledge of the effect of this combination upon the yield of cut flowers after the plants were benched in the greenhouse was considered desirable. There was no blight among the field plantings in 1940; nevertheless, a greater yield of flowers was obtained from the plot sprayed with Bordeaux 5-5-50, calcium arsenate 1 pound, Penetrol ½ pint. Although not a significant difference, the results nevertheless revealed the tolerance of the plants to the best fungicidal treatment for controlling blight. There was no foliage injury from this treatment (Table 21).

A similar experiment was conducted in 1941. The plants were sprayed four times in the field, June 2, 12, 24, and July 3. On July 17, 140 plants from each of the sprayed plots were benched in 48 square foot benches and sprayed further on July 18 and August 5. Dow Potato Spray was included in the tests since it represented a proprietary combined copper and calcium arsenate powder which would appear to be more practical to use than combined homemade Bordeaux mixture and calcium arsenate. For the first and second application it

was used at 3 pounds to 50 gallons of water, and then reduced to 2 pounds in 50 gallons; but both were injurious and the treatment was discontinued. Yield records of flowers from September to June, inclusive, showed a very favorable response from field treatments with homemade Bordeaux 4-4-50 combined with 1 pound of calcium arsenate (Table 22). There was no injury. The large excess of lime in Bordeaux 4-4-50 or 5-5-50 exerts a buffering influence upon calcium arsenate, and a deficiency of lime or an excess of calcium arsenate in the mixture can be seriously injurious to carnations.

TABLE 21. YIELD OF CARNATION CUT FLOWERS IN THE GREENHOUSE FOLLOWING SPRAYING TREATMENTS IN THE FIELD IN THE SUMMER OF 1940. Variety, Nina Brener. Waltham.

Fungicide *	Yield, November to April			
	One	Two	Split	Total per Sq. Ft.
Basic Copper Sulfate 2 lb.-50 gal.	207	334	125	13.8
Bordeaux 5-5-50, Calcium Arsenate 1 lb.	300	302	138	15.4
Yellow Cuprocide ¾ lb.-50 gal.	209	328	163	14.5
Cuprocide 54, 1 lb.-50 gal.	235	294	171	14.5
No Treatment	221	264	173	13.7
	Yield, November to May			
Bordeaux 5-5-50, Calcium Arsenate 1 lb.	375	406	145	19.2
Yellow Cuprocide ¾ lb.-50 gal.	289	418	173	18.3
No Treatment	297	348	180	17.1

* Penetrol, ½ pint to 50 gallons, was used with each treatment.

TABLE 22. YIELD OF CARNATION CUT FLOWERS IN THE GREENHOUSE FOLLOWING SPRAYING TREATMENTS IN THE FIELD IN THE SUMMER OF 1941. Variety, Nina Brener. Waltham.

Fungicide *	Yield, November to April			
	One	Two	Split	Total per Sq. Ft.
Dow Potato Spray**	710	307	169	24.7
Yellow Cuprocide ¾ lb.-50 gal.	722	361	210	26.9
Bordeaux 4-4-50	813	391	244	30.1
Basic Copper Sulfate 2 lb.-50 gal.	716	410	212	27.8
Bordeaux 4-4-50, Calcium Arsenate 1 lb.	855	395	227	30.7
No Treatment	704	291	195	24.7

* Penetrol, ½ pint to 50 gallons, was used with each treatment.
** 3 pounds to 50 gallons for the first and second applications; then reduced to 2 pounds to 50 gallons. Both were injurious and the treatment was discontinued.

Discussion and Recommendations

Serious occurrences of carnation blight are limited to susceptible varieties and to seasons marked by frequent rainfall. In field culture, control of the disease is possible only by protecting the plants with fungicides, but carnation growers generally have been handicapped in controlling the disease in the field by lack

of power spraying equipment. Frequent and thorough coverage of the plants with a dense driving mist of spray is needed to control the disease. Hand sprayers are both impractical and inefficient. Dusting has never given satisfactory results. The disease is not a problem if the grower will dispense with field culture, at least for his susceptible class of stock. If the grower must field the plants even for the months of May and June only, frequent protection with fungicides would be desirable, particularly in areas along the sea coast or where field culture is prolonged into July.

On the basis of studies at Waltham, growers have been encouraged to use homemade Bordeaux mixture 4-4-50 plus a suitable spreader, such as fish oil, linseed oil, or Penetrol, which have been used at the rate of 1 pint to 100 gallons of spray. Where serious outbreaks of the disease have occurred, the addition of 1 pound of calcium arsenate to 50 gallons of Bordeaux spray has been recommended to strengthen the fungicide. Without the spreader the control of the disease can be unsatisfactory. It is emphasized that good results may be expected only from **thorough plant coverage and frequent application.**

The applications should begin shortly after the plants are established in the field and continue at 7-10 day intervals until the plants are housed. Spraying the plants in the flats just before fielding is practical and can be very desirable. If rainfall is not too frequent the interval between treatments may be extended to two weeks. One or two additional applications may be desirable after the plants are established in the benches. This schedule of treatments has given increases in yields of cut flowers in both blight and non-blight years, and no injurious effect upon the plants has been apparent.

SANITATION BETWEEN PLANTINGS IN THE GREENHOUSE

The sanitary disposal of the carnation stock and litter at the end of the producing season is an important pest control measure. Diseased plants dispersed among the litter are loaded with the inoculum of various pathogenes and at the end of the year the stock usually harbors thrips, red spider mite, and other miscellaneous pests.

In the removal of the old plants a considerable population of insect pests and fungous spores is left behind or redistributed in the houses making it possible for infestations to become established in the new planting. Too frequently the carnation rubbish is deposited outside the greenhouse and left there after the houses are replanted, thus providing a source from which the pests are redistributed throughout the newly planted stock.

The plants and the adhering pests can be destroyed reasonably well just before the cleaning-out operations are started by fumigating with strong concentrations of sulfur dioxide generated from burning sulfur; naphthalene base vapors; hydrocyanic acid gas; or chlorpicrin. Both sulfur dioxide and chlorpicrin are complete pesticides. Naphthalene and hydrocyanic acid gas are more specifically insecticidal and not fungicidal. The use of these fumigants is recommended only for individual isolated houses. The seepage of the fumigant into adjoining or attached houses containing plants can cause damage in spite of all reasonable precautions taken to avoid it. Growers who may be interested in disinfecting the old stock with chemical fumigants between plantings should first consider all of the particulars and hazards involved in their use. After a fumigation of twenty-four hours or longer and the complete destruction of the growth, the houses should be aired well and the litter removed and burned. Such disinfestation of the greenhouse would help greatly in preventing sudden infestations of pests in the newly planted stock.

SUMMARY

The important fungous diseases of carnations in Massachusetts are spot, blight, and canker caused by *Alternaria dianthi* Stev. and Hall; root, crown, or foot rot caused by *Fusarium culmorum* (C. W. Smith) Sacc., *F. avenaceum* (Fr.) Sacc., and other species of Fusarium; Fusarium branch rot or wilt caused by *Fusarium dianthi* Prill. & Delacr.; and stem rot caused by *Rhizoctonia solani* Kühn. Distinctive symptoms of disease are associated with each pathogene and wilting is common to all of them.

Infection of carnation plants by *Alternaria dianthi* readily occurs in a humid atmosphere even in the absence of plant injuries. Injuries to the foliage by drought, infestations of the red spider mite, and other causes contribute to infection in the field.

Fusarium culmorum and related species infect the plants through injuries in the roots, stems, and branches and through snags and adhering remnants of stems and leaves.

Plant injuries are required for infection by *Fusarium dianthi*, which attacks the roots, stems and branches.

Rhizoctonia infection is generally more successful through injuries; but infection is readily obtained by mixing the fungus with the soil and providing warm, moist conditions.

All of these pathogenes attack cuttings in the sand and plants in the various subsequent stages of culture. The cut surface at the base of the cutting is a favored point of attack. The natural cracking or checking at the base of the cutting offers a favorable point of infection especially by the various species of Fusarium.

The optimum temperatures for spore germination and growth of the pathogenes are approximately 75° F. for *Alternaria dianthi*; 77°-80° for *Fusarium culmorum*; 80° for *Fusarium dianthi*; and 86°-88° for *Rhizoctonia solani*.

The incidence of disease in the cuttings and in the young stock subsequent to rooting is intimately associated with either infection latent in the cutting or superficial spore inoculum. Such contamination is derived from unhealthy stock plants or from normal plants adjacent to unhealthy stock plants. The transfer of Rhizoctonia is excluded from this concept.

The use of new and clean sand after each crop of rooted cuttings is recommended, and the potentialities of used sand for rooting further crops of cuttings is indicated.

The direction of the cut through the stem in the preparation of the cuttings is not important in relation to rooting, but a smooth, clean cut leaving no loose remnant of tissue is preferred in relation to disease control. The injured ends of leaf stubs left after trimming the cuttings offer infection courts for Alternaria blight under favorable conditions, but the hazard is usually negligible.

Immersion of the cuttings for 15 minutes in a 1-1,000 solution of potassium permanganate, ¼ ounce to 2 gallons of water, encourages rooting and provides some degree of disinfection of superficial inoculum conveyed by the cuttings to the sand.

Potassium permanganate was the most effective chemical considered in the tests. The various hormone materials used in practice to improve rooting are not fungicidal and no significant advantage was shown from treating the cuttings with both a hormone material and potassium permanganate. Powdering the base of the cuttings with a 10 percent Fermate or Arasan dust gave good control of wilt caused by the fungus *F. dianthi* without harming root action.

All-year culture in the greenhouse is an effective method of controlling Alternaria blight. Fielding the plants increases the hazards from disease. The prevalence of disease increases as transplanting into the greenhouse from the field is delayed beyond the first week in July.

Care in lifting and transplanting to avoid breakage is an important disease control measure. The oldest or earliest-propagated stock is most easily injured and generally less tolerant of changing and unfavorable growing conditions, and more subject to wilt diseases. For disease-susceptible varieties, delaying propagation until January might be advantageous in some years.

Infection and the advance of wilt diseases are favored by excessive watering, overhead watering, warm greenhouse temperatures, and stagnant, moist atmosphere. Such extreme conditions are likely to exist from July to September.

Setting the plants deeper than the roots at any of the stages of culture encourages infection notably by the Rhizoctonia stem rot fungus.

Fumigation of carnations with naphthalene base materials for controlling infestations of the red spider mite represents a notable improvement over the former practice of syringing the plants with strong sprays of water. The change has contributed to better disease control and to an improvement in the quality of the flowers.

Diseased plant remains and plants wilting from disease are potential sources of inoculum and should be disposed of in a sanitary manner.

The young plants and flowering stock require distinct care. The spread and continuity of disease may be controlled by a careful supervision of the young plants. Entire flats of young plants or classes of stock should be discarded in the event of a progressive loss from disease among them. Segregation of the two classes of stock is desirable, and a house devoted wholly to young plants is recommended.

Distinct contrasts in the susceptibility of carnation varieties to *Alternaria dianthi* and *Fusarium dianthi* are shown. The pedigree of several varieties has been traced in an effort to find the source of resistance and susceptibility to *Alternaria dianthi*. The culture of varieties resistant to disease is recommended where a serious disease problem persists.

The subject of soil sterilization with heat and chemicals in relation to disease and weed control is reviewed. The effect of treating new and used soil in the benches with chlorpicrin was not significant when the plants were grown in the field in apparently infested soil. The sterilization of the potting and flatting soil by any acceptable method is very desirable.

Powdered naphthalene, copper compounds, and calcium arsenate are lethal to the conidia of *Alternaria dianthi*. Lead arsenate, lime, and sulfur materials are not toxic. The toxicity of several chemicals to the spores was determined by different techniques.

Good control of Alternaria blight was shown in small-scale tests with Bordeaux combined with calcium arsenate and fish oil, and with dusting mixtures containing naphthalene, calcium arsenate, monohydrated copper sulfate, and lime. In epidemic years significant control of blight in the field was shown by protective treatments with Bordeaux mixture 4-4-50 combined with calcium arsenate 1 pound and Penetrol ½ pint. Increases in yields of flowers are shown. Calcium arsenate alone was injurious. Dusting materials gave unsatisfactory control. Satisfactory results from spraying require frequent treatments with a power sprayer beginning after the plants are fielded in May and continuing to benching time in the greenhouse, or early July. Spraying treatments are desirable for susceptible varieties, but only where field culture is practiced.

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